BRITISH WELDING JOURNAL

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By S. Wise

Institute of Welding Report of Council

BWRA Annual Report

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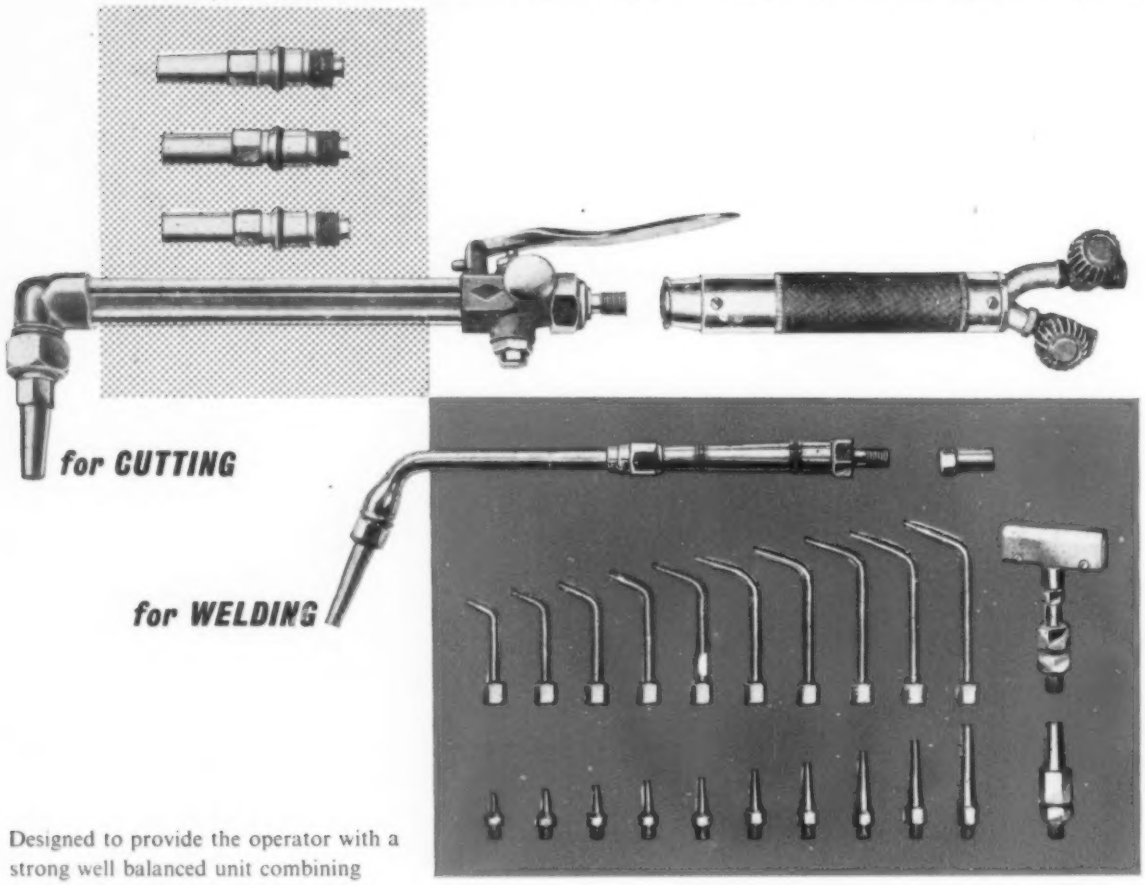

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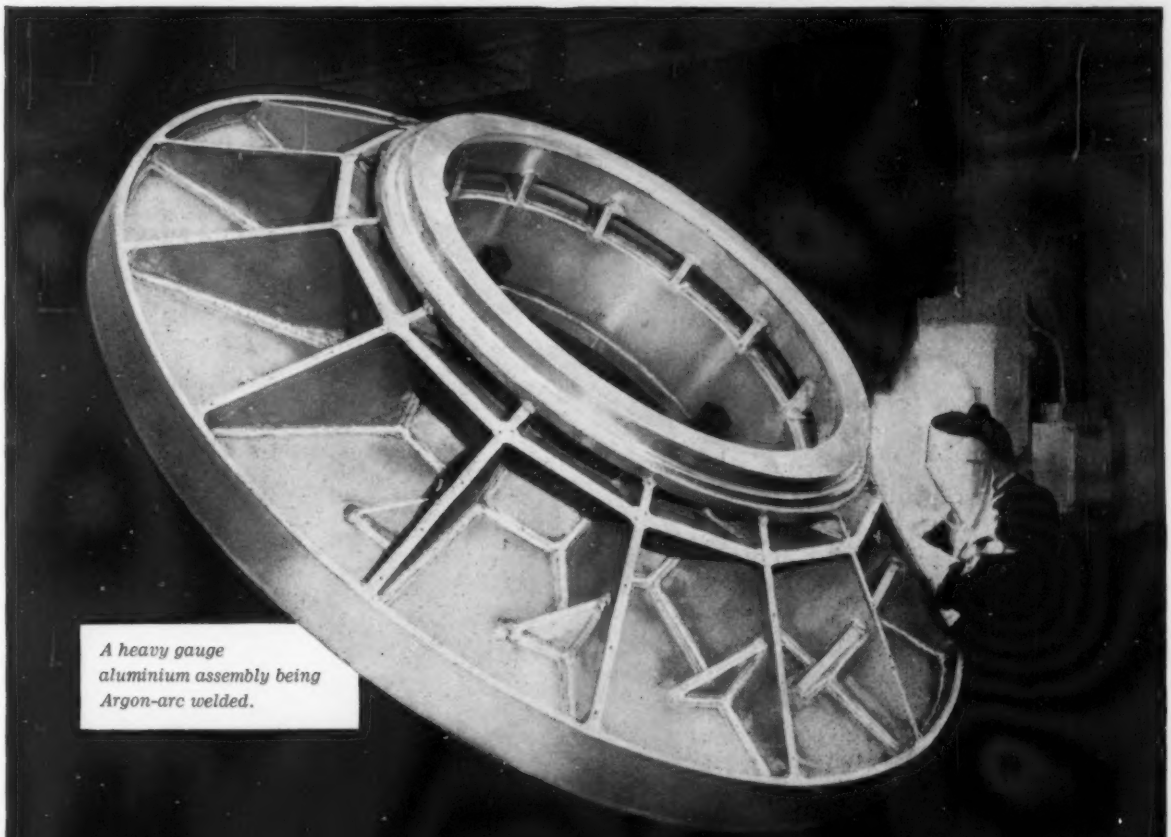

A heavy gauge aluminium assembly being Argon-arc welded.

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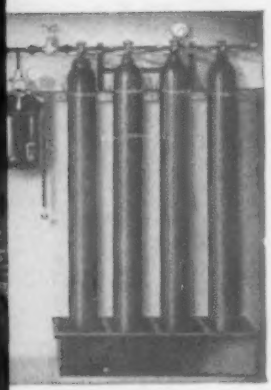
Photograph illustrating the FUSARC/CO_2 process by courtesy of Quasi-Arc Limited



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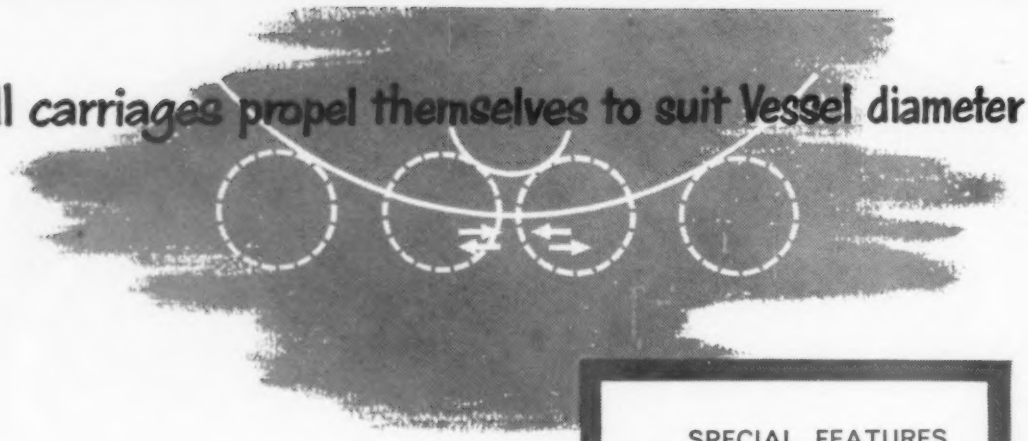

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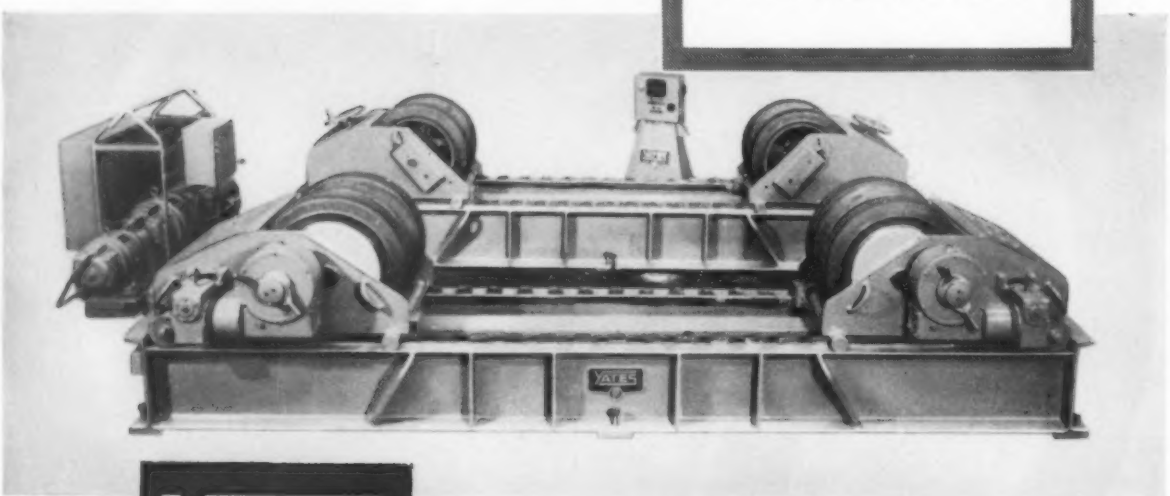

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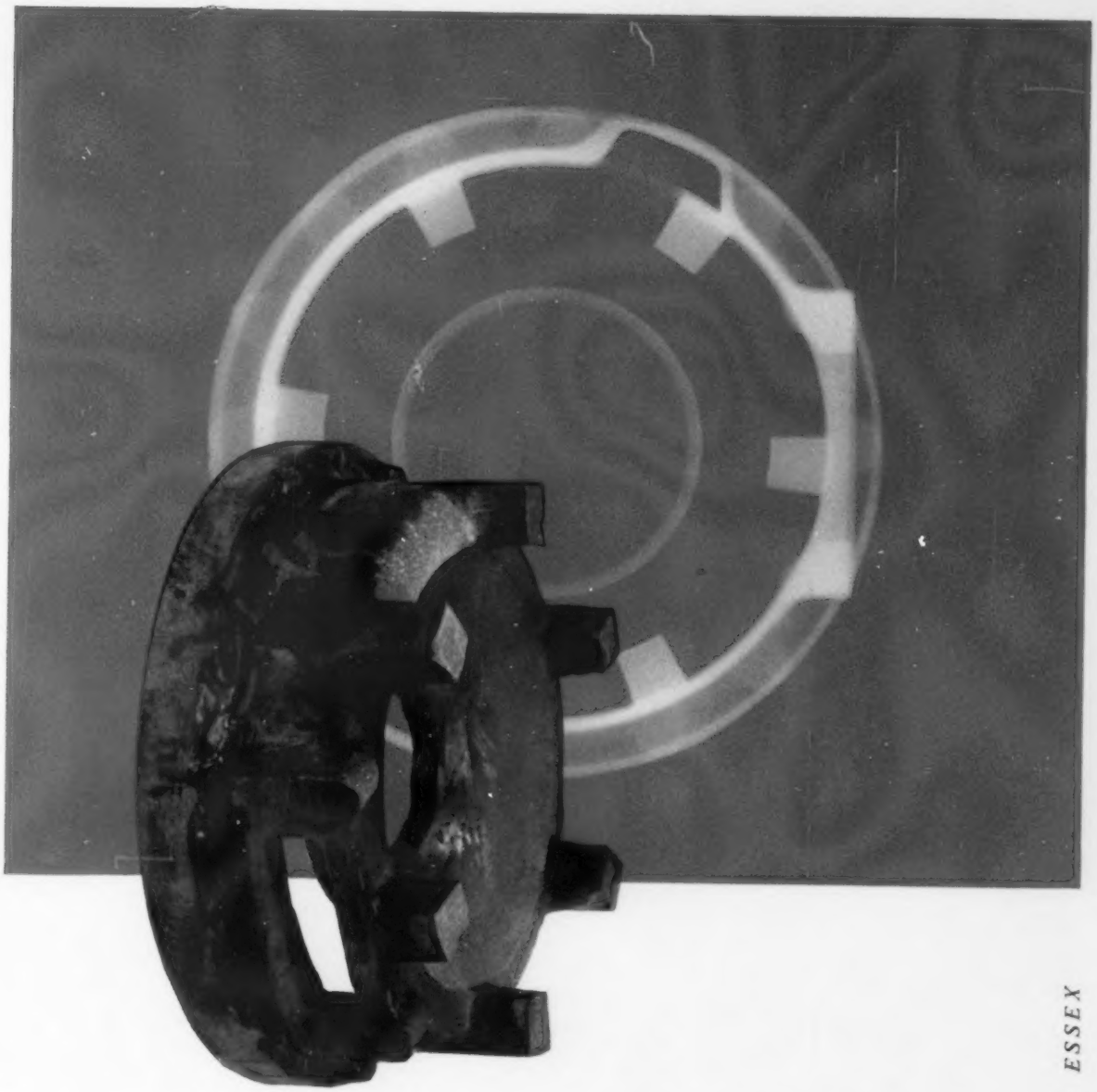

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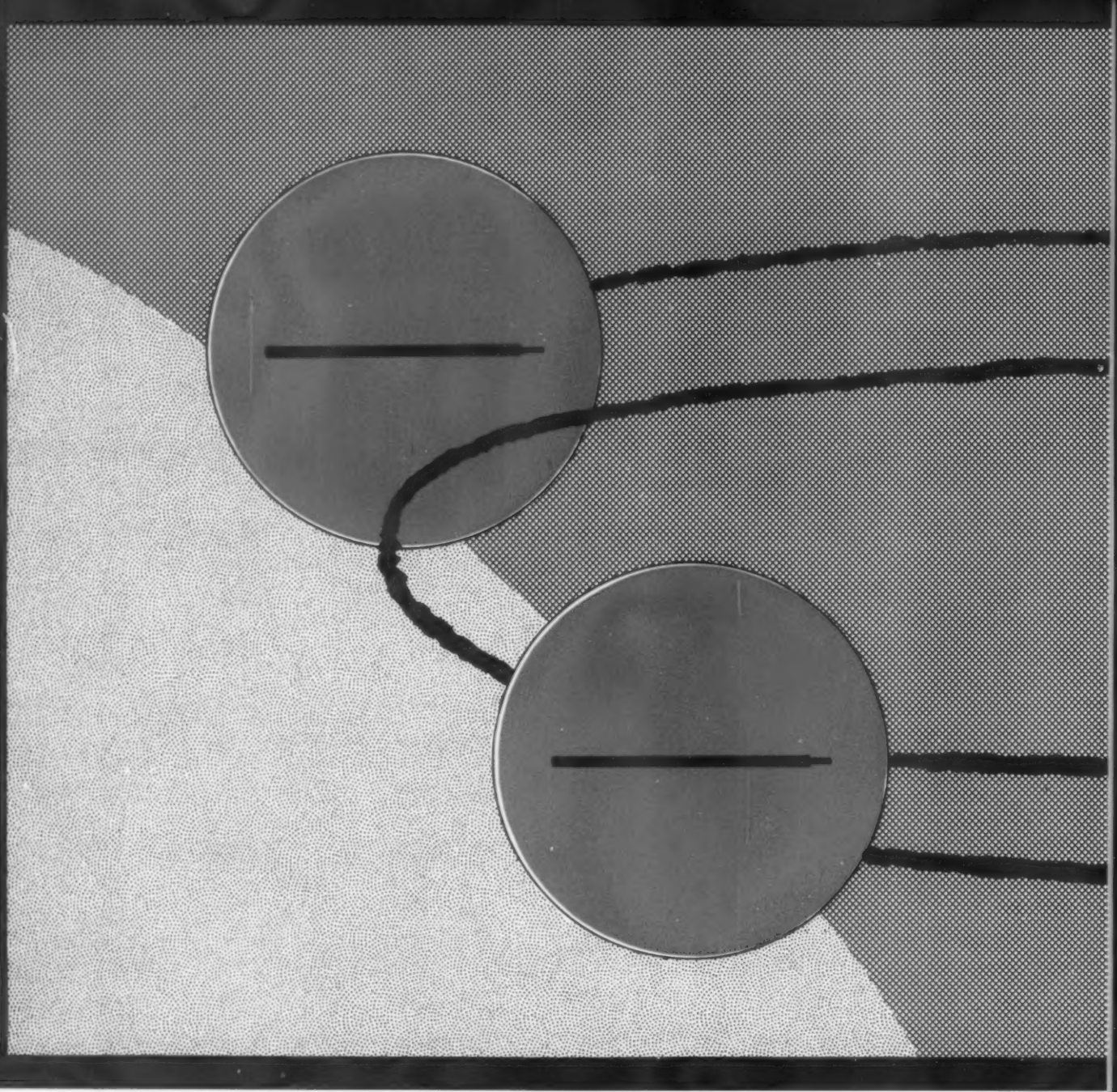

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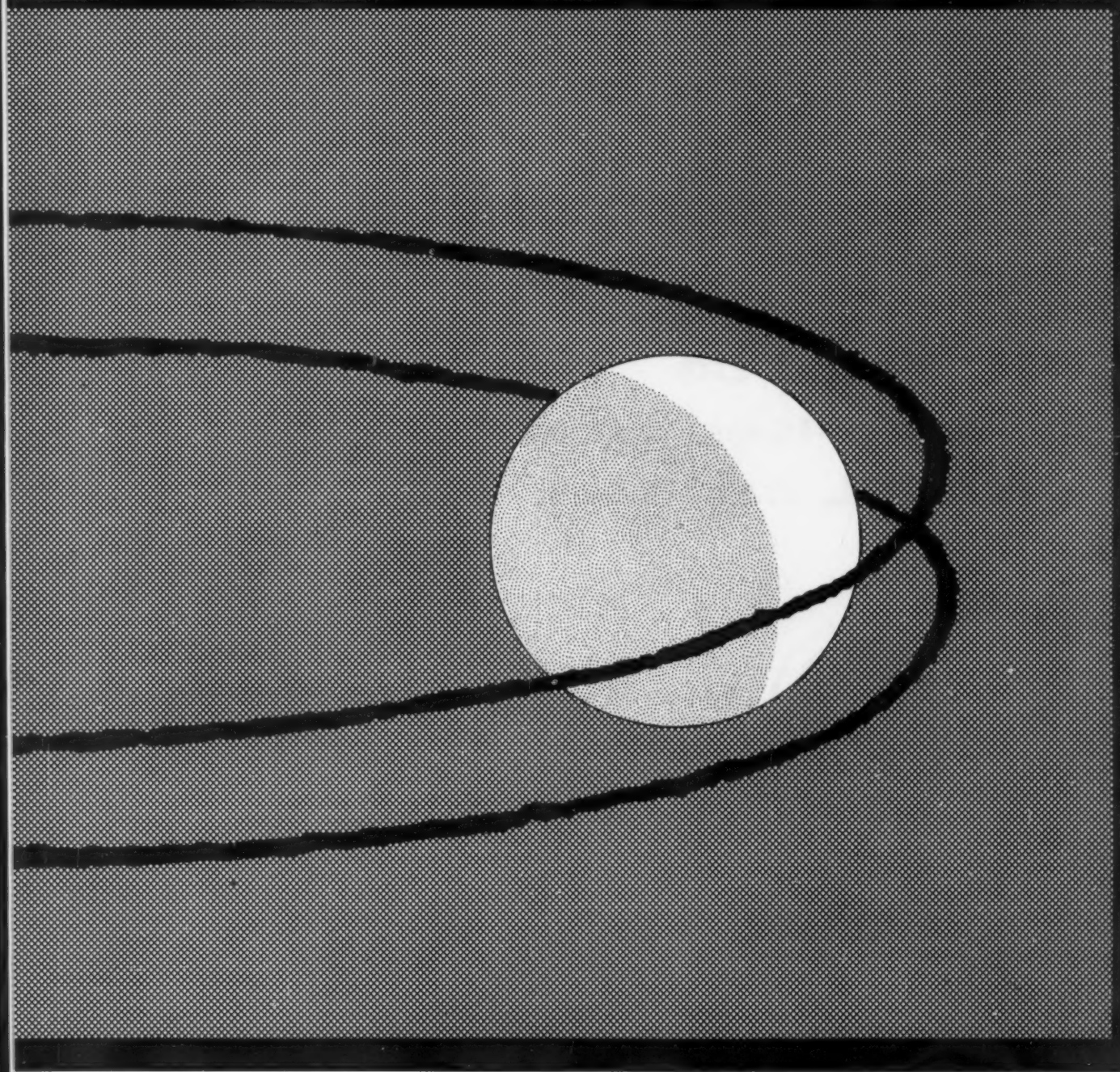

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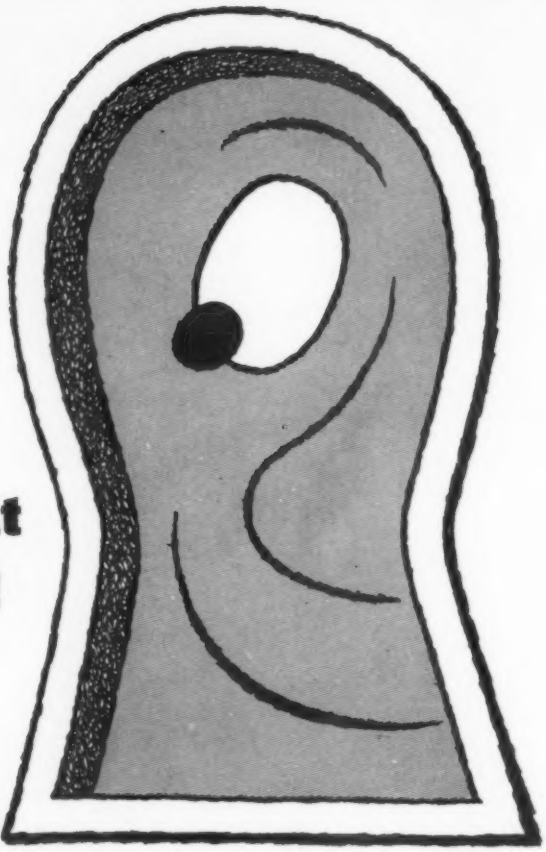

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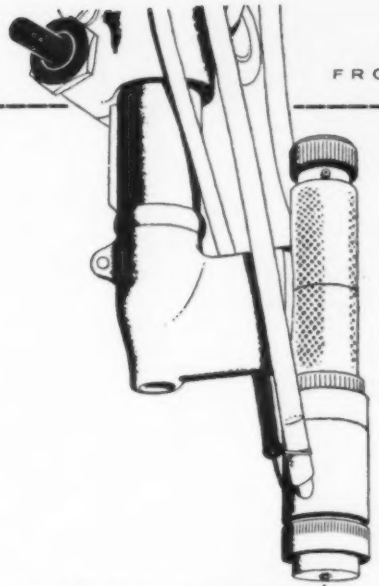

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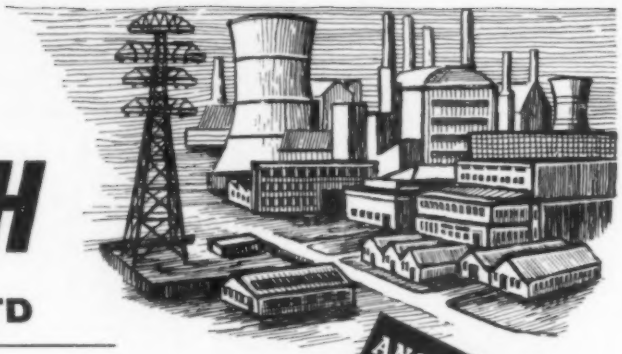

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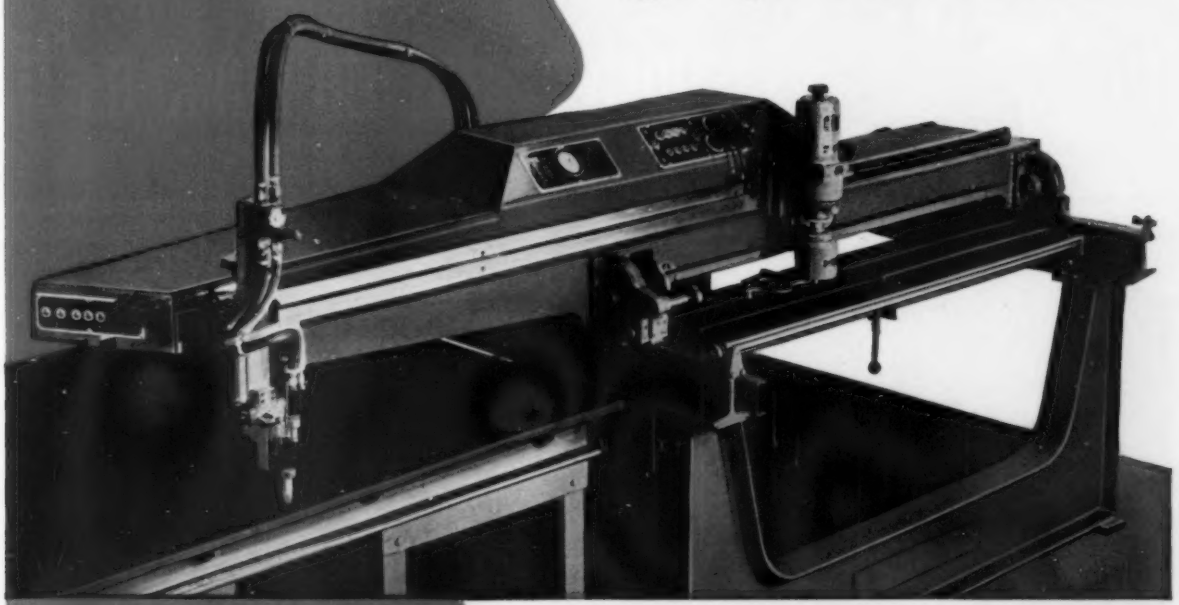

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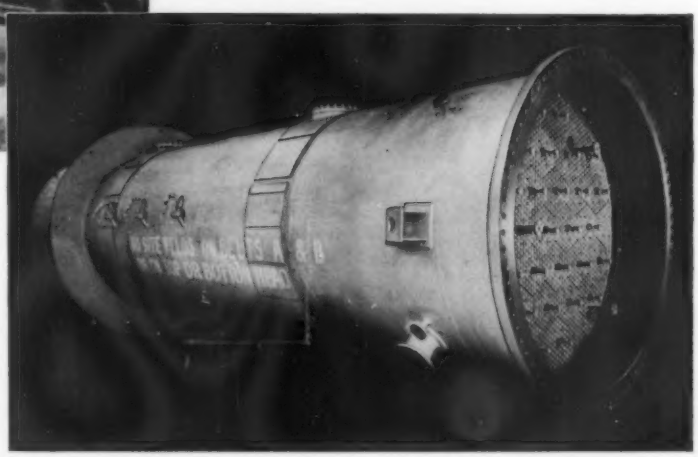

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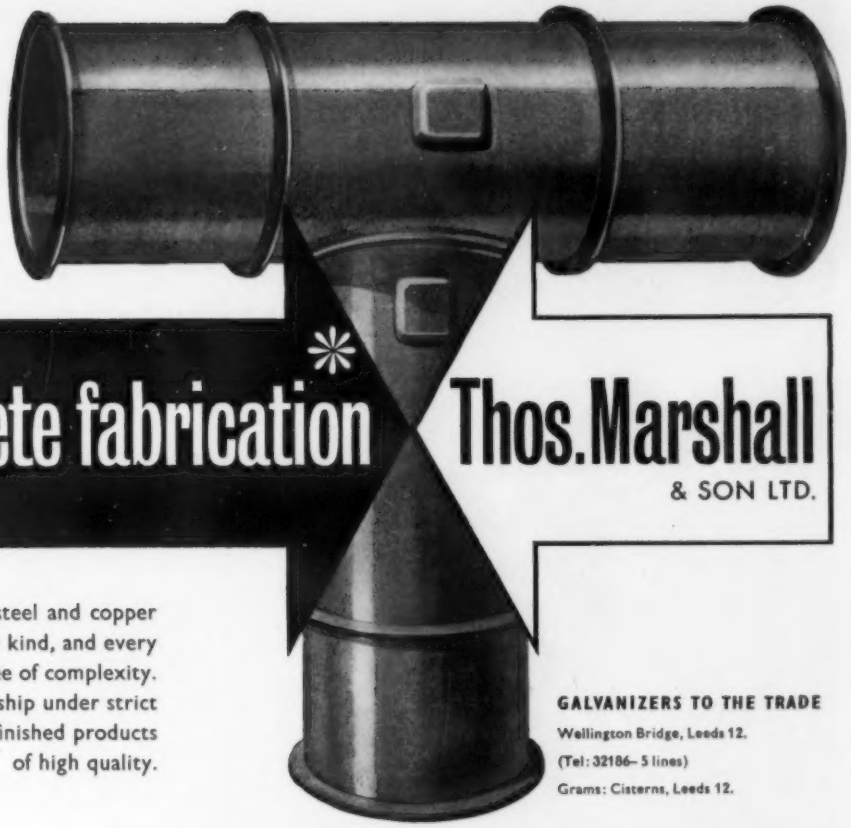

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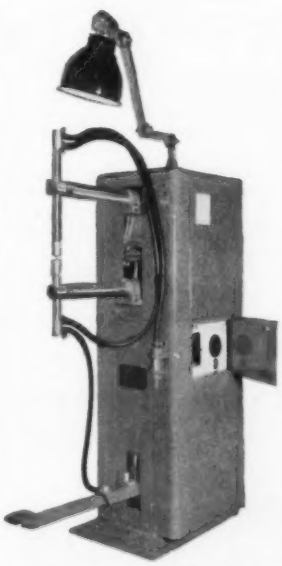

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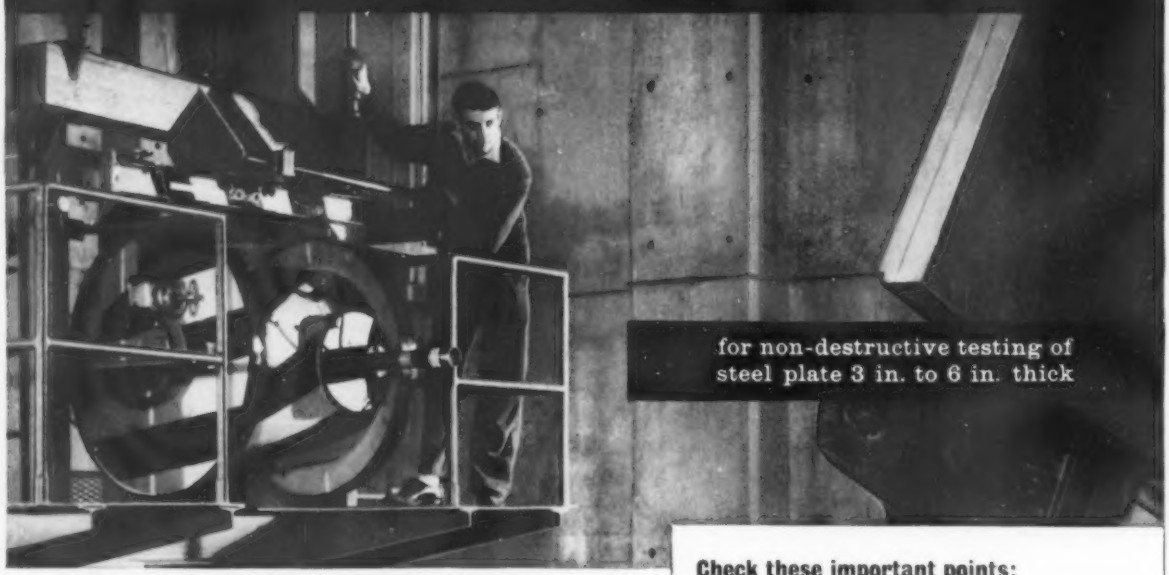

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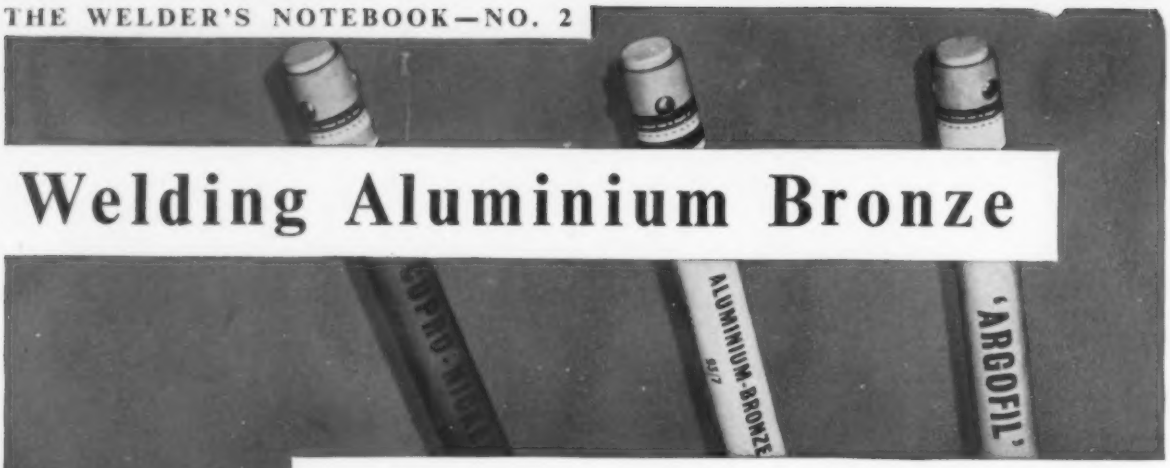

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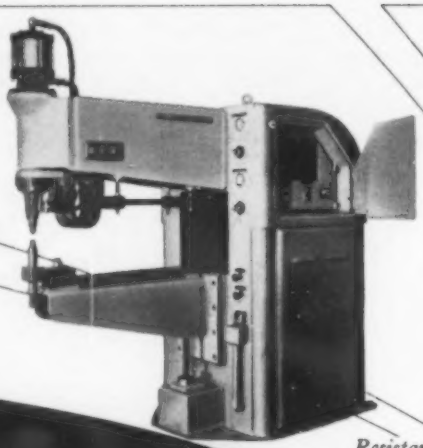

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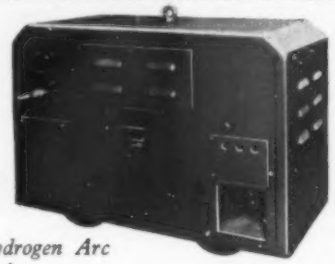

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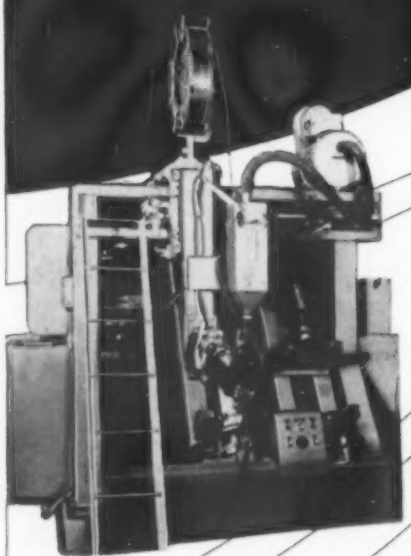

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INTERNATIONAL INSTITUTE OF WELDING

Strength of Components Repaired by Welding

By S. Wise, A.M.I.MECH.E., A.I.M.

The paper considers the effect of different types of weld on the fatigue resistance of engineering components made of mild steel or of high-tensile steel. It describes how fatigue failure may occur owing to the incorrect application of welding during repair work, because of the lower fatigue strength of welds, or because of changes in the stress distribution in the structure caused by welding. Examples are given of fatigue failures that have occurred in engineering structures because of welding, and the significance of internal defects in welds is also discussed.

ALTHOUGH engineering maintenance work has been made considerably easier by the advent over the past thirty years or so of reliable welding processes, the very ease with which worn parts can be built up, and cracks welded or patched, has often tended to conceal the fact that the repaired article will inevitably have a shorter life, due to the application of welding, than its original life in the unrepaired state.

It is the purpose of this paper to draw attention to some of the effects of welding on the subsequent life of engineering components, but, since the subject as a whole is vast, attention will be concentrated on dynamically loaded components which may be, at ambient or near ambient temperature, subjected to fatigue failure, and in general to parts made of steel.

The examples quoted are generally taken from railway experience. A modern organization such as British Railways uses welding extensively in the construction and maintenance of locomotives, rolling stock, bridges, structures, and permanent way, and since good records are generally kept, and the same components return to the same workshops over and over again, an excellent opportunity is given for studying over a long period of time the efficiency of various welding techniques. This is particularly so with British Railways, in whose workshops the use of welding as a maintenance tool expanded enormously in the period 1930–40 and who own large numbers of identical steam locomotives, carriages, and wagons.

Butt Welds in Mild Steel

Well-made butt welds in mild steel are generally regarded by engineers as having a static strength equivalent to that of the unwelded plate and a fatigue strength about 80% of the unwelded plate, when the weld is ground flush. This means, however, that the use of butt welding as a method of repairing lengthy cracks in steel structures is not wholly satisfactory, as can be seen more clearly in the following example.

Repairs to locomotive frames

In Great Britain steam locomotives have always been constructed with plate frames, usually of mild steel 1–1¼ in. thick. Some classes of engine have, over a period of years, developed fatigue failures at the

Paper presented at the Open Session of the Annual Assembly of the International Institute of Welding, held at Opatija in June 1959.

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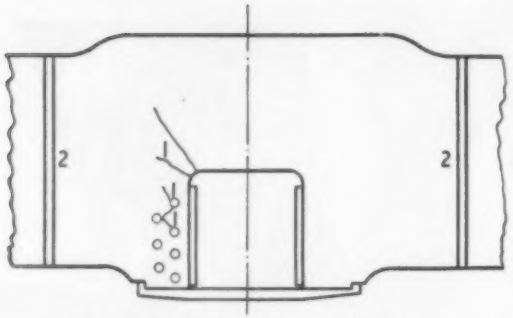


1—*Typical locomotive plate frame at axlebox guides, showing:* (1) *cracks previously repaired by welding;* (2) *position of butt weld when cracked plate is replaced with a new section (present-day practice)*

radius at the top of the driving horn space, the cracks following approximately the path shown in Fig. 1. Cracks also develop between the rivet holes that secure the axlebox guides to the frame. The practice of repairing the cracks by welding developed in the mid 1930's, but it was very soon noticed that whereas it had originally required perhaps seven years from the time the engine was built for the cracks to develop, once welding repairs had been made the same locomotive was found to be cracked in approximately the same position every time it came in for a heavy repair ($1\frac{1}{2}$–2 years). This led to the opinion that poor quality welding was responsible for these early failures, and indeed macroscopic examination of some welds showed them to be very bad; this was due principally to the method of preparation then in vogue, *i.e.*, chain-drilling along the crack followed by chipping which did not completely remove the profiles of the drilled holes.

The quality of the preparation and therefore of the weld were then considerably improved, but little change in the general situation could be observed; this was followed by the introduction in some works of radiographic examination of butt welds in main frames. The use of X-rays immediately showed a number of defects in the welds which had not previously been suspected, among them being the commonly occurring 'tramlines' or parallel lines of slag inclusions, and as a result a great deal of attention was then paid to welding techniques. Techniques for upward vertical welding and horizontal welding in the vertical plane were developed, and operators were trained in these techniques.

Vertical butt welds made by the two-operator technique and of high radiographic quality were thus produced, but failure of the repaired frames continued at an apparently undiminished rate.

Horizontal-vertical welds were found to be extremely difficult to execute and so they were avoided as far as possible.

Examination of some of the failures showed that frequently the new cracks did not follow the centre of the weld, but more usually lay in the base metal to one side of the weld, often in the heat-affected zone, and sometimes following the path of undercut at the edge of the final runs. Often serious defects (by radiographic standards) in welds played no part in a subsequent fatigue failure.

This situation led to the realization that the frame plate in the area in which cracks occurred very definitely had a finite fatigue life, and that, as the stress gradient in the area was very gradual, a relatively large volume of metal existed all of which had more or less exhausted its fatigue life. Repair by welding merely had the effect of temporarily closing the existing cracks, with the probability that new cracks formed almost as soon as the locomotive resumed working, and slowly spread through the plate. Once this was appreciated it was obvious that the correct though more expensive repair was to remove the whole fatigue-damaged material and to replace it with a new section arranged so that the butt welds were in areas where the stress was relatively low. This repair could be reasonably expected to have a fatigue life at least equal to that of the frame as originally built. (Fig. 2).

As set down in this manner the conclusion seems extremely obvious, but it should be remembered that

(a)

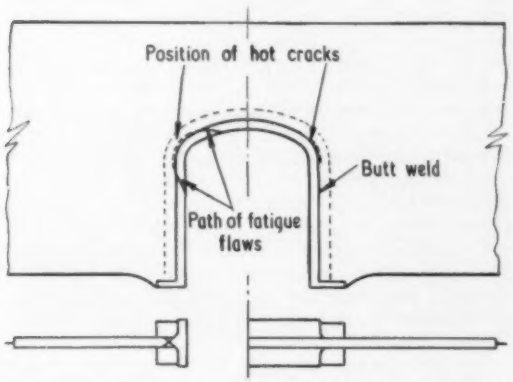
(b)

2—*Repair of cracked steam locomotive frame:* (a) *the part containing the crack has been cut out and a new piece of frame plate is fitted in readiness for welding;* (b) *the finished repair showing the new piece welded in. The most common failure takes the form of diagonal cracking from the corners of the axlebox horn gap*

much of this work was done 15–20 years ago, when knowledge of the effects of fatigue was less widespread than it is today. Moreover, in the particular circumstances it was difficult to believe at the time that the defects revealed in welds by radiography were not the prime cause of the subsequent poor service performance.

However, the principal object of describing at length the history of frame failures is to show that repair by welding of fatigue cracks in a structure can be only a very short-term solution to the problem, and that the proper solution is firstly to remove fatigue-damaged material, and secondly to place the welds in areas of low dynamic stress. Once again this may seem obvious, but even today appreciation of the significance of fatigue is not as general among engineers as it should be, whilst in many industries it frequently happens that the engineer responsible for maintenance work at one period is no longer in that position when machines are returned to the workshops on the next occasion, so that continuity of experience is lost.

Even when butt welds are placed in areas in which the dynamic stresses are relatively low, fatigue failure may still be initiated by certain classes of weld defect. In another example of butt welding in locomotive main frame plates a fatigue failure was eventually traced to small hot cracks in the top run of a butt weld. The weld at the top was relatively wide and the last run deposited was very shallow, having been weaved from one side to the other so as to fill up undercut on each edge. In addition, the whole length of the weld had a **U** configuration so that the residual welding stresses were high across certain sections of the joint. At these points small hot cracks had formed in the thin top run. The welds had subsequently been ground flush, but in such a manner that the grinding marks ran parallel to the cracks and obscured them. Although the dynamic stresses were relatively low they were sufficient to propagate the cracks as fatigue flaws (*see* Fig. 3). The work of Frost[1] shows that the fatigue limit of cracked mild steel is of the order of $\pm 3\frac{1}{2}$ tons/sq.in. so that a relatively normal level of working stress will suffice to propagate a fatigue failure if cracks are present in a weld. There is therefore a very good case for magnetic or dye penetrant testing of all welding repairs on components which are subsequently to carry dynamic stress, particularly if the parts have been subjected to much restraint during welding.



3 –*Fatigue fracture in locomotive frame having welded axlebox guides. Fracture commenced at hot cracks in final run of welding*

Influence of other welding defects

Probably most maintenance welding is done by the manual metal-arc process, and when multi-run butt welds are made by this method it is difficult to produce welds of high radiographic quality without very great attention to details of technique, choice of electrodes, procedure and so on. The two most common faults are porosity and slag inclusions, and if the finished welds are subject to radiographic inspection it has to be considered what action is needed if defects of this type are present. This is, in effect, questioning "Are these defects dangerous if the component is dynamically loaded?" (It should be recognized that, in the ordinary steels at least, the defects described have almost no measurable effect on the static tensile properties of the joint when present in the amounts likely to be found in reasonably competent welding).

In metals subjected to fatigue loading the surface is by far the most vulnerable part. Defects such as slag inclusions and porosity do not usually occur at or near the surface. It is therefore considered that porosity or slag, either as small isolated inclusions or as thin elongated 'tramlines' are much less serious than has been presumed in the past.

There is unfortunately very little conclusive evidence on the effect of slag inclusions and porosity on fatigue strength, principally owing to the difficulty of measuring the severity of defects in a weld, and also to the large number of fatigue tests required to reach valid conclusions. Fatigue tests made on welds containing slag inclusions in various degrees have been reported by Warren[2] among others, but it is worth noting that statistical analysis of Warren's figures indicates that there is no significant difference in the test results between "sound welds" and those having "heavy slag at the root". This does not necessarily mean that there is no real difference in the fatigue strengths of such welds, but that the difference is probably relatively small, and that a very large number of tests would be required to demonstrate the difference convincingly. The much more important defects are cracks and those having a crack-like form, such as lack of fusion or of penetration. During a long series of fatigue tests on rails butt welded by a manual arc process and subjected in service to fluctuating vertical bending it has been observed that small areas of non-fusion of 1 mm radius at the base of the weld are more deleterious to the fatigue strength of the welded rail than are quite large slag inclusions occurring at 6–7 mm above the base of the weld. As a result, a special ultrasonic technique using surface wave probes has been developed to detect lack of fusion in welds made in the track.

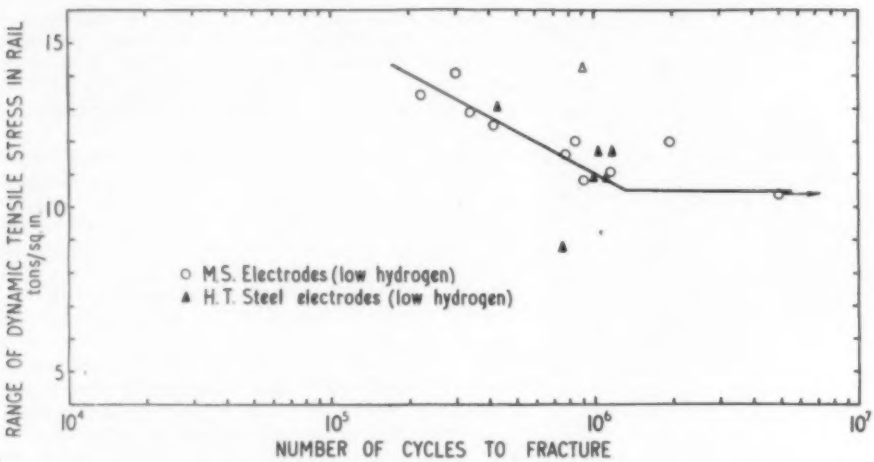
It is also probable that the effect of residual stresses on the fatigue limit, as demonstrated by the Russian work described by Trufyakov,[3] is far more important in reducing fatigue strength than are the commonly occurring defects of porosity and slag inclusions. This is particularly true of welding maintenance work, where it may be necessary to add new pieces to an otherwise complete structure, where the opportunities of developing a suitable welding sequence are necessarily reduced, and where stress relieving may be im-

possible because of the need to preserve machined surfaces. Similar arguments apply where extensive building-up or reinforcement has been done to part of a more or less complex integral structure.

Higher tensile steels

The foregoing relates specifically to mild steel. The welding of higher tensile steel is a completely different problem and it must be emphasized that generally the fatigue strength of high-tensile steel is reduced to the level of that of mild steel by almost any weld, and this fact must always be borne in mind when considering a welding repair on a high-tensile component.

Originally, a very large number of failures were caused by the indiscriminate welding of high-tensile steels, but the dangers of hardening in the heat-affected zone are now generally recognized and the need for preheating or the use of basic or low-hydrogen coated electrodes is well appreciated. The present problem, now hard-zone cracking can be relatively easily overcome, is that the dangers of the inherently low fatigue strength of welds in high-tensile steel may be overlooked. When made with ordinary low-hydrogen electrodes even the highest quality welds will still have only the fatigue strength appropriate to the mild steel electrode: if higher tensile electrodes are used the sensitivity of the weld metal to internal notches, such as small slag inclusions, increases sharply, and most erratic values of fatigue strength are obtained. This is clearly shown in Fig. 4, which shows the results of fatigue tests made on two batches of welded rails. The first represents the results obtained using a low-hydrogen electrode having a tensile strength only slightly above the normal, *i.e.*, about 40 tons/sq.in., whilst the second shows the results of tests using a much more highly alloyed electrode material giving a deposit of tensile strength of about 54 tons/sq.in. The erratic results obtained in the second example should be noted.



4—*Pulsating-bending fatigue tests on flat-bottom rail welded with different electrodes*

Fillet Welds

Unlike the butt weld, which when well made and ground flush can have a fatigue strength very close to that of the unwelded steel, the fillet weld by its nature introduces a geometrical stress concentration of some magnitude. This means that dynamic stress ranges greater than 6 tons/sq.in. cannot be permitted in components carrying fillet welds, or to which, in the course of maintenance, pieces of steel have been attached by fillet welding.

Fatigue failure in fillet welds may commence either at the toes of the fillet, or at the root; if dynamic loads are to be withstood it is important that the welds should have a good smooth contour, concavity of the weld being preferable to convexity, coupled with good root penetration and freedom from slag entrapment beneath the weld. Generally, magnetic crack testing is advisable, since crater cracks or contraction cracks in the main body of the weld will lower the fatigue strength even more. Intermittent fillet welds are particularly dangerous since the stress concentrations are increased at the ends of the welds. Continuous fillets should therefore always be provided in structures subject to repeated loading.

Even lower values of safe dynamic stress may be associated with fillet welds which transmit considerable loads. In fatigue tests on a welded structure, in which the main tensile load was transmitted by fillet welds, failure occurred in the fillet weld after 10^6 cycles at a stress range little more than 3·8 tons/sq.in. Whilst this may be an extreme case, it has to be remembered that fillet welds may be called upon to transmit quite large loads when they are used to attach apparently unloaded parts, such as pads, to the surface of a plate or rolled section member carrying dynamic loads. If the pad is welded at both ends it will of necessity experience the same strain as the member to which it is welded, whilst if it has considerable thickness the load required to extend it during each cycle, which can only be transmitted by the fillet welds, may be high, although the pad itself may make little contribution to the overall stiffness of the member to which it is welded.

The attachment of pads to dynamically loaded members is fraught with danger, even though the pad may be intended as a reinforcement. If the main member is subjected to bending the pad must either

be sufficiently long to increase the stiffness of the main member, or it must be carefully tapered so as to produce a gradual change in stiffness over the affected area. The structure should be considered carefully to decide whether the deflections imposed are such that they can only be reduced by unnecessarily great increases in the structure weight. In that case local reinforcement of a flexible structure becomes extremely difficult. For example, one class of passenger vehicles working on a short route having very sharp curves had a history of failures in the framework of the bogie. A programme of repair and modification by stiffening up the frame (particularly at right-angled connections) was then put in hand. This resulted in even more rapid failure than before, because fracture then occurred at the junctions of the stiffeners.

In general, it has to be appreciated that the stiffness of a tee joint fillet-welded on both sides is very considerably greater than the older form of riveted tee joint. If the loading system is such as to apply high deflections to one or other plate there will be high stresses at the toes of the fillet welds, which may lead to early failure. In the late 1930's several locomotive tenders were constructed wholly by welding (Fig. 5). Stiffener members welded to the sides were often subject to considerable surge forces when the tank was partly full of water. These surge forces were transmitted through the fillet welded joint so as to cause fatigue failure in the tank side plates. Repeated welding of these cracks proved to be no solution (as with the frame failures) and eventually it was decided to change the design to one using flanged stiffeners riveted to the side plates. With this design fatigue failure was avoided although leakage through loosened rivets still occurs.

Welding Repairs on Bridges

Many metal railway bridges are now very old, and their maintenance is a serious problem particularly where they are exposed to considerable corrosion. In addition, they may have to be strengthened to carry heavier traffic than that for which they were originally designed: in both instances welding is commonly employed.

5—Locomotive tender in course of construction. The interior gusset plates, which are subject to surge forces from the water, are shown directly connected to the tank side with intermittent fillet welds

Plate girder bridges, in which the web is joined to the flanges by riveted angles, often suffer badly from corrosion of the web plate immediately above the angles, and if unchecked this may lead to complete separation of the web from the flanges. The repair of this type of damage is difficult, especially when the bridge must be kept open to traffic. One method is to fit a patch plate over the corroded web plate on both sides, extending the patch if possible so as to ensure that sound metal is available in the web plate at the welds. The patch plates are then welded with vertical fillets to the web, and with horizontal fillets to the top and bottom angles.

This type of patch does not suffer from the disadvantages of patches on plates transmitting tensile forces, as previously described. The main load on the web is shear, and this is transmitted into the patch by compression through the welds. The only other difficulty that may arise is that due to the fillet welds in the web plate. If these are discontinuous (bad practice from the corrosion viewpoint) or if defective welds occur there is the possibility that fatigue failures may occur in the web because of shear stresses, since the stress concentration effect of a given notch or discontinuity is greater in a shear field than in a tensile–compressive field. However, in railway bridge main girders there is a mitigating effect in the relatively low rate of accumulation of cycles of stress. A normal plate girder bridge will experience only one cycle of stress per train, and even at as many as 100 trains a day, thirty years must pass before the main girders have experienced 1,000,000 cycles of stress.

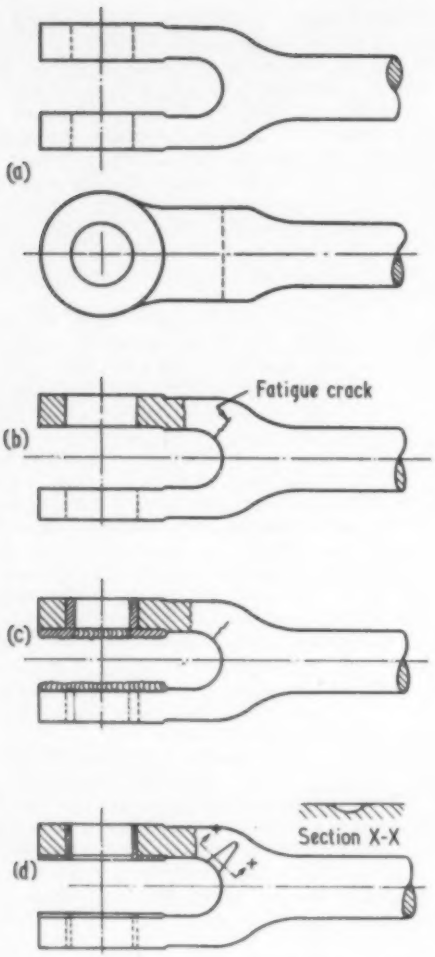
Cross girders and rail bearers in the older bridges are a different matter, since these may experience a cycle of stress for each axle passing over the bridge, which may mean a rate of accumulation of stress cycles fifty times greater than that of the main girders. For this reason welding repairs likely to cause severe stress concentrations in these members must be considered very carefully.

Reinforcement

Reinforcement or building-up of worn parts has been practised for so many years now that it is perhaps one of the best known of welding maintenance operations. However, one or two comments are given, based on experience in maintaining a number of old locomotives at a time when spare parts were extremely difficult to obtain. This situation inevitably leads to requests for the building-up of worn parts of running gear, such as coupling rod joint-pin holes, spring links, and miscellaneous items of valve gear, many of the latter being case hardened.

After a time it was found possible to standardize many of these repairs, which occurred with reasonable frequency and where, if the standard instructions were adhered to carefully, little trouble was to be anticipated. As a general rule, however, most dynamically loaded components were stress relieved after welding, and were carefully inspected for cracks after machining.

The more difficult examples, including valve gear parts with case-hardened surfaces, were given special attention. So far as possible, the welding of case-hardened surfaces was avoided, but in one or two



6—*Emergency welding repairs to case-hardened fork-ended valve gear component:* (a) *Initial condition;* (b) *fork end softened and case-hardened surface machined off before welding;* (c) *after preheating and building-up by arc-welding;* (d) *weld deposit machined to size and crack tested.* (*Note: The fatigue crack is not welded.*)

exceptional instances worn areas in these components were successfully reinforced. The method adopted was firstly to soften the hardened component, then to machine off the carburized layer from the surface to be reinforced. Welding was done after careful preheating to avoid cracking in those carburized edges which were of necessity left adjacent to the area to be welded. After welding, the component cooled slowly and when machined it was very carefully examined with a magnetic flaw detector. Subsequent re-carburizing was rarely done, as the whole purpose of a repair of this nature was to prolong the life of an old engine by another year or so; wear was not an important factor. Despite the obvious risks, no subsequent failures occurred, probably because of the low level of dynamic design stress in these components. Evidence of this was given by several valve gear links which were found on initial inspection to have fine cracks on the case-hardened surface owing to cold 'setting' of the fork ends at a previous repair, without there being any indication that these cracks had subsequently spread under fatigue loading.

Where fatigue cracks were encountered it was customary to avoid welding, and the general practice with cracks up to about $\frac{1}{4}$ in. deep was to file them out, ensuring their complete removal by magnetic crack testing, and then to round off and polish the edges of the groove, so as to replace a crack by a smoothly contoured highly-polished groove, having a much smaller stress concentration factor (Fig. 6). Within the limited life demanded for these repairs, this practice also was quite successful, and it is often to be preferred when the temporary repair of parts containing shallow fatigue cracks is imperative.

On the whole it seems that the reinforcement by welding of worn machine parts presents little danger, even when the components convey relatively high dynamic stresses, provided that the following principles are adhered to:

(i) Welding should be of good quality. Areas of non-fusion or slag inclusions exposed by subsequent machining may reduce the strength by 50%.
(ii) Unless it is known that dynamic stresses are low in the part concerned, welding of the higher tensile steels should in general be avoided, since the reinforced area is unlikely to have a fatigue strength much greater than that of mild steel weld metal, whatever electrode is used.

Conclusion

This paper has described briefly some of the difficulties and dangers likely to be encountered in the repair by welding of steel components subjected to alternating or fluctuating stresses in service. Despite the emphasis on the dangers involved in this practice it is not intended to be a general condemnation of the use of welding in these circumstances but rather a plea for careful consideration, *before* the work commences, of the value and direction of the dynamic stresses involved, of the residual stress system introduced by welding, and of the effects of the added material (if any) on the stiffness and deflection characteristics of the component.

A few examples of failures as a result of welding have been quoted, but it must also be remembered that welding is still an important, widely used, and successful method of repairing many thousands of components for British Railways.

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INTERNATIONAL INSTITUTE OF WELDING

Reclamation of a 30-ton Steel Casting

By G. Gordon Musted

This paper presents a typical example of the problems encountered in the field of reclamation and repair work. Details are given of the method employed to salvage a 30-ton cast steel drop hammer frame, which was considered to be beyond reclamation. It shows how the casting was made fit for further service by the combined use of oxy-acetylene cutting and heating, metal-arc and submerged-arc welding, thus preventing a serious interruption in production.

MANY failures of plant and machines are directly attributable to inadequate maintenance. Thus cracked foundations or loose fixing bolts are a common cause, and these defects need to be rectified before any question of repair can be considered.

In planning the repair itself, it is important to ascertain the type of material involved, because this will indicate whether or not the repair can be carried out successfully by welding. A knowledge of the material composition will indicate the welding technique and the types of electrode or filler rod to be used, as well as the heat-treatment that would be required.

The variety of conditions and the nature of repairs are so diverse that it is difficult, if not impossible, to formulate any specific rules or methods to be used for reclamation and repair work by welding.

The Problem

For the work described, the problem was how to replace, without the need for preheating, a defective section in the main body of a 30-ton cast steel drop-hammer frame, which was a solid mass about 5ft. 6in. thick (Fig. 1).

The general principles for welding steel castings are fairly well established, and although certain limits are placed on repairs to new castings, which are usually supervised by Lloyd's Register or the Admiralty, decisions regarding works' reclamations or repairs are entirely at the discretion of the management.

Joint Preparation

In the present instance the defective section was not considered to be safe for further service, and it was replaced with a mild steel insert. This was accepted as a piece 8½ in. thick, the final inch to the full 9½ in. thickness of the casting being made up with a submerged-arc weld deposit. The edges of the insert were prepared to a double J butt joint with the root face about ½ of the thickness from the base (Fig. 2*a*).

The main body of the casting in the defective area was first prepared by chipping and grinding to remove any surface cracks. A projecting 'razor edge' was removed by flame cutting, leaving an edge at an angle of about 60°, and the upper surface was ground flat (Figs. 2*b* and *c*).

The next operation was to build up the surface of the defective area of the casting to a shape to match the prepared edges of the insert. To bridge the full gap at the ends of the insert (Fig. 2*d*), would have been useless, for the surrounding metal was so massive, and

1—*Detail of defective casting. The piece that broke away was 9½ in. thick and formed part of the guide for a drop hammer*

the amount of weld metal needed so large, that an unnecessary amount of heat would have developed across the joint with consequent greater contraction. Although the outer edges were free, the high restraint in the longitudinal direction would have led to possible cracking.

It was therefore decided to use a 'buttering' technique by superimposing runs of mild steel deposit until the required shape had been reached. The

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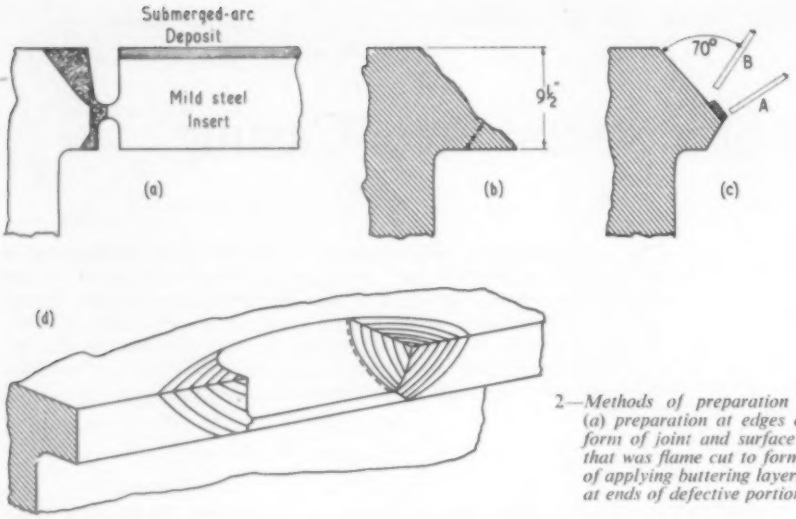
This paper, which was prepared by the author only a few weeks before his death, was presented by his wife at the Public Session of the Annual Assembly of the IIW, held at Opatija, Yugoslavia in June 1959.

The late Mr. Musted practised as a Welding Engineer and Consultant in Birmingham.



2—*Methods of preparation and welding procedure adopted: (a) preparation at edges of steel insert, showing also final form of joint and surface deposit; (b) projection on casting that was flame cut to form suitable welding edge; (c) method of applying buttering layers; (d) final shape of built-up portion at ends of defective portion*

buttering is simply a re-surfacing of a part in such a way that it is completely dissociated from the main joint, and it takes no part in the final local heat-treatment to which a welded joint of normal proportions is subjected.

The buttering runs were deposited from $\frac{1}{4}$ in. dia. low-hydrogen type electrodes in the H.V. position, as shown in Fig. 2*c*. Firstly, a straight bead was deposited as at *A*, with the electrode held at an angle of 90°. This formed a shelf on which subsequent runs were laid, as at *B*, without removing the slag, and with the electrodes held at about 70° to the side of the work. By this technique it was possible to make continuous bead deposits, the slag falling down out of the way. The slag was easily removed when the superimposed runs were made to build up the surface to the required profile.

At the two curved 'ends' of the fracture (Fig. 2*d*) runs were built up to fill in the space, and were squared off to suit the prepared ends of the insert.

Because of the mass of the casting and the relative narrowness of the insert, it was decided not to use preheating, but the chill was first removed from the casting by means of pieces of red hot metal placed around the heavy sections. The heat developed from the buttering runs was also allowed to dissipate slowly with the help of similar hot metal.

At the end of this operation the profile had been built up to a double J shape to match the edge of the insert (Fig. 2*a*).

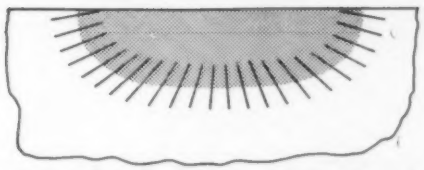
Welding-in the Insert

The next stage in the repair was to make the final butt joint between the steel insert and the casting. The insert was held in position by a crane while it was tack welded into position, and angle supports were welded to the underside (Fig. 3). It was then checked for alignment.

The final welding of the joint was carried out with $\frac{5}{16}$ in. and $\frac{1}{4}$ in. dia. electrodes, which were deposited longitudinally along the top and bottom until the U joints were completed. The insert was made oversize in width, and run-off plates were attached at each end, so that the finished edges of the welds, at *C* in Fig. 2*d*, would be sound after cutting away the surplus material.

When the final runs were made to build up the top face to the required height, short transverse beads were deposited across the joint into the sound casting, each alternate run being staggered in length to avoid an abrupt line in the area of thermal disturbance (Fig. 4). The object of these runs was to help distribute the thermal stresses and to minimise the danger of

3—*Steel insert tacked in position and supported on angle struts*



4—*Cross beads applied before final surface layers were deposited by submerged-arc welding*

cross-sectional bead cracking. The remaining space was then filled in with longitudinal runs deposited by the submerged-arc process.

Finished Repair

The finished repair is shown in Fig. 5, which also gives some impression of the size of the weld deposits. This illustration also shows a 3-in. dia. bolt which had to be replaced. The original bolt hole was badly fractured, and a special heavy nut was made for welding on the casting to accept the new bolt. The nut was held in position during welding by means of a copper tube.

It had been intended to machine the inside of the finished repair, but the setting up and the welding had been done so accurately that this was not necessary; thus the expense of transporting the frame to another department, as well as the cost of machining, were saved. The surfaces of the repair were finished to the satisfaction of the shop manager by chipping, grinding, and the use of flexible abrasive discs, followed by draw-filing.

Conclusions

This brief description of a welded repair has shown how the practical application of welding and cutting can reclaim a heavy piece of equipment at one tenth of the cost of a new part. The delivery time for a new casting was twelve months, and the production time saved by being able to put the repaired frame into service with little delay must also be taken into account.

5—*Finished repair before dressing the welds*

Acknowledgment

The author wishes to acknowledge his thanks to all those who helped to make this reclamation possible.

INTERNATIONAL INSTITUTE OF WELDING

Reproducibility of the CTS Weldability Test for Low-Alloy Steels

The results are described of a co-operative investigation by five laboratories on the Controlled Thermal Severity Test, which has been chosen by Sub-Commission B of Commission IX of the International Institute of Welding as the most reliable basis for determining weldability of low-alloy steels.

Tests were carried out under identical conditions on the same material and with the same electrodes. The agreement of the results was such that the CTS test is considered to be satisfactory for the scientific investigation of phenomena associated with heat-affected zone cracking, and as a comparative test for steels, electrodes, and welding procedure.

SUB-COMMISSION B of Commission IX is concerned with the weldability of steels related to their transformation characteristics. Its terms of reference are:

(*a*) To study the scientific background of the transformation phenomena of steels subject to the repeated heating and cooling cycles occurring in heat-affected zones of welds, with a view to providing a sound basis for recommendations to be made to Commission IX.

(*b*) To decide the means by which recommended temperature cycles for the welding of hardenable steels may be determined.

Since it was considered to be the most reliable test available, the Sub-Commission has adopted the Controlled Thermal Severity (CTS) Test, developed by the British Welding Research Association, as a basis for the determination of weldability.

The tests described in this report were undertaken to investigate the reproducibility of the test carried out with identical material by various laboratories. Those participating were the British Welding Research Association (G.B.), Colvilles Ltd., Research Department (G.B.), Institute de Soudure (France), Mannesmannforschungsinstitut (Germany) and Oy Esab (Finland).

The specimens were selected and distributed by the Research Department of Colvilles Ltd.

Development of the CTS Test

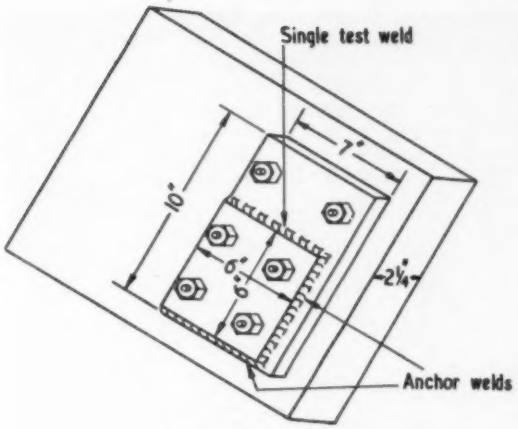
The Controlled Thermal Severity test is a restrained fillet weld test developed from earlier tests of a similar type. Such tests consist essentially of the deposition of a fillet weld under predetermined conditions, and the subsequent examination of transverse sections of the weld for cracks in the heat-affected zone of the parent plate.

The first test of this type was the Reeve Test[1] in which a fillet weld was made under conditions of extremely high restraint and with a very high rate of cooling in the heat-affected zone of the parent plate (Fig. 1). The test weld was made between two plates of the steel to be examined which were bolted together to a thick base plate, and then further joined to each other by fillet welds around three sides of the upper plate. The contact surfaces between the two test plates, and between the lower test plate and the base plate, were ground to ensure good heat transfer. The base plate served the two functions of increasing the rigidity of the lower plate, and of increasing the volume of metal into which the heat from the test weld could be dissipated. Thus the Reeve Test represented, both in restraint and cooling rate, the most severe conditions that could ever be obtained in practice. A disadvantage of this test was that large amounts of plate were required for each test weld, and also that the cooling conditions were always at one extreme of the possible range.

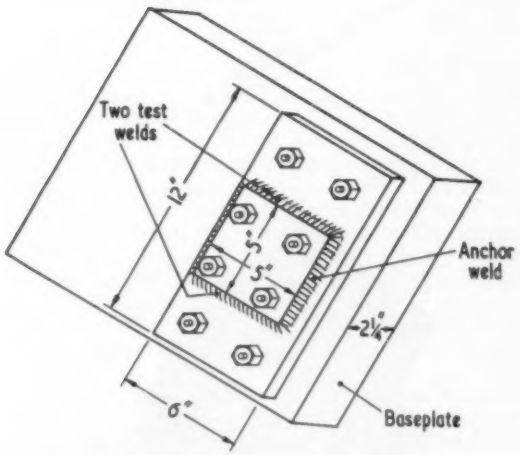
To economize in material, Dearden and O'Neill[2] proposed the modification of the Reeve Test shown in Fig. 2. In this test, the essentially 'infinite plate' cooling conditions were retained, together with the very high restraint, but provision was made for two test welds by moving the top plate to the centre of the length of the lower plate, and by using only two anchor welds.

For both these tests, the original published descriptions suggested that cracks in the heat-affected zone

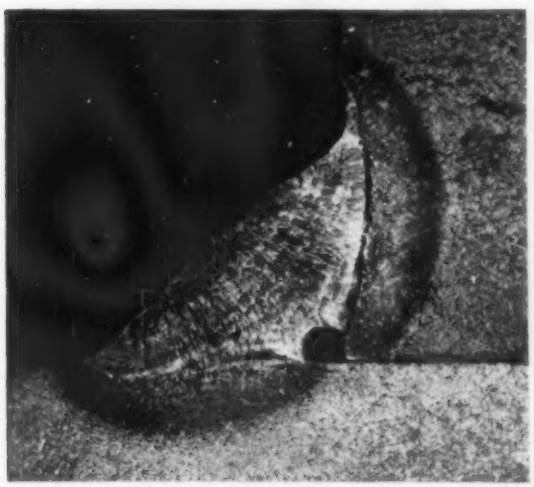
A slightly abridged version of Document IIW/IIS–7–58 (ex doc. IX–213–58) of Sub-Commission B, Commission IX—'Behaviour of metals subjected to welding', which was drafted by P. H. R. Lane of the British Welding Research Association.



1—*Reeve Test assembly*



2—*Modified Reeve Test assembly*

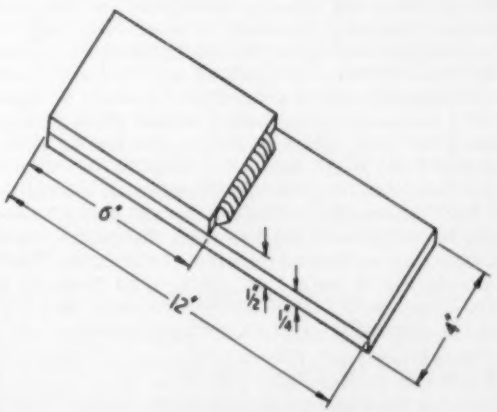


3—*Typical cracked weld from Reeve Test* ×5

should be detected by the use of magnetic crack-detection fluid, utilizing either the remanent magnetism from the welding process, or a small permanent magnet. Sections for examination were cut from the test weld(s) and roughly polished on a face perpendicular to the direction of the weld. A typical example of a cracked specimen from one of these tests is shown in Fig. 3.

Whilst the above tests could be used conveniently for comparing the weldability of various steels, using various electrodes, the conditions of restraint and cooling were so extreme that the results provided little indication of the experience to be expected in service. The tests provided a large measure of security since, if cracks did not occur under the test conditions, it was most unlikely that they would ever be experienced in any fabrication. However, with such a severe test, a material might be rejected which, under service conditions considerably less severe than those of the test, could be welded satisfactorily. The Controlled Thermal Severity test was developed so that the severity of the cooling conditions could be varied.

An examination of the important factors in a weldability test of the type being discussed showed that the considerable external restraint, applied by both the Reeve and the Dearden and O'Neill Tests, was not necessary for the initiation of heat-affected zone cracking. Unrestrained fillet tests were carried out.[3] These consisted simply of welds made between two plates which merely rested on top of each other (Fig. 4). Typical heat-affected zone cracks were obtained in such tests when the cooling rate conditions were sufficiently severe. Further tests used



4—*Unrestrained fillet test assembly*

smaller test plates and smaller base plates than were used in the Reeve Test, and it was found that cooling rates sufficiently high to cause considerable heat-affected zone cracking could be obtained with a much smaller assembly than had been used by Reeve.[4] It was also shown that with the smaller assembly the maximum cooling rate required could be obtained by using increased thicknesses for the test plates and no base plate. On the basis of these investigations the Controlled Thermal Severity test shown in Figs. 5 and 6 was developed.

Description of CTS Test

The CTS test consists of a fillet weld laid between two plates with the dimensions shown in Fig. 5. The upper plate is fixed to the lower by means of a single bolt and two anchor welds, and is placed with its centre line 2 in. from one end of the lower plate. After the anchor welds are made, the test assembly is allowed to cool to room temperature, and is then supported on a suitable heat insulated jig so that the test welds may be laid successively in the downhand position. After the first test weld, the assembly is allowed to cool to room temperature before the second test weld is made. The rate of cooling of the weld will be strongly affected by the heat input, which will depend on the size of the test weld. The experimenter should therefore specify the size of weld required.

A certain amount of external restraint is provided in the specimen, for although the unrestrained fillet weld test showed that this external restraint was not necessary for the *initiation* of heat-affected zone cracks, it was found that restraint increased both the length and width of the cracks, which were thus more easily detected.

Wide variations in the severity of cooling can be obtained by varying the geometrical conditions governing the heat flow away from the weld. This may be done either by varying the number of paths available for heat to flow away from the weld, or by varying the thickness of the material constituting these paths. The two test welds in the CTS test differ in the number of paths available. That numbered 1 in Fig. 5 has two paths available, and that numbered 2 has three.

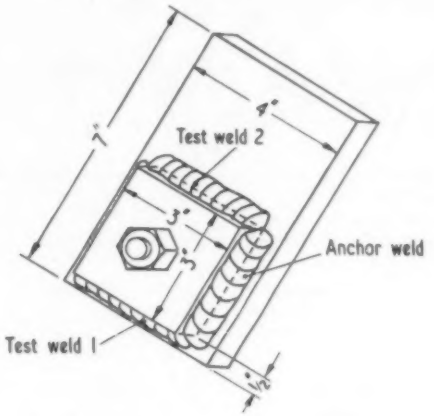
To assist in describing the geometry of the test piece that controls the cooling conditions, a series of 'Thermal Severity Numbers' is used. The basis of these numbers is the heat flow along one path of plate ¼ in. thick; this has been defined as TSN 1 and would be attained by a weld on the edge of a plate ¼ in. thick. TSN 2 indicates the equivalent of two paths through plate ¼ in. thick, which could be provided by a butt weld in ¼ in. thick plate, or a weld on the edge of ½ in. thick plate. In a fillet weld, such as is used in the CTS test, the thicknesses of the top and bottom plates must be considered, together with the protrusion of the bottom plate beyond the weld. For example, if both plates in Fig. 5 were 1 in. thick, weld 1 would be TSN 8, and weld 2 TSN 12. For the welds in a CTS test, the thermal severity numbers are given by:

For weld (1) in Fig. 5, TSN = 4 (b + t)
For weld (2) in Fig. 5, TSN = 4 (2b + t)

where b is the thickness of the bottom plate and t that of the top plate, both in inches.

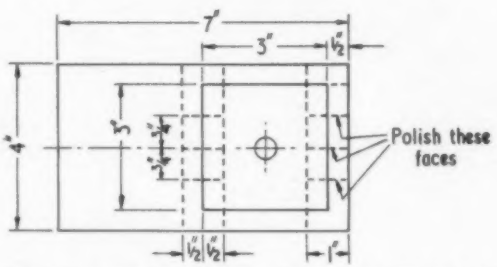
After both test welds have been laid, the test assembly is allowed to cool to room temperature, and is left undisturbed for some time to ensure that all potential cracks develop. There is some evidence that cracking does not occur immediately the test assembly cools to ambient temperature, but that cracks continue to appear, and to increase in length, for a period of many hours after welding. Accordingly, the Sub-Commission recommends that all test welds should be left for 48 hr before sectioning.

After this period, the test welds are cut from the assembly and sectioned according to the scheme shown in Fig. 7. The faces indicated are prepared for microscopical examination. The preparation should be carried out with the utmost possible care, since the material in the heat-affected zone has been subject to severe cooling conditions, and is undoubtedly in a metastable state. Accordingly, machining operations, such as sawing or surface grinding, should be carried out with light feed rates and an adequate flow of coolant. It is suggested that after such machining

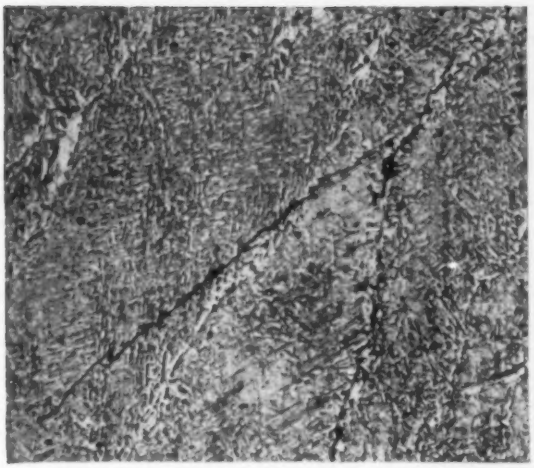


5—*Controlled thermal severity test assembly*

6—*CTS test specimen on insulated stand ready for welding*



7—*Method of sectioning CTS test. (Sawcuts indicated by dashed lines)*



8—*Typical fine crack from CTS test* ×250

operations at least 40 microns of material should be removed from the surface in the subsequent rough polishing stage.[5] The surfaces to be examined should be prepared in the usual way for metallographic examination, proceeding through successively finer grades of abrasive paper, and finishing with a polishing process. If electrolytic polishing is used, the process must be carefully controlled to produce a polished surface of high quality, since otherwise it can lead to spurious markings on the polished surface, which can easily be mistaken for cracks. If mechanical polishing methods are used, modern diamond powder techniques are preferable to the use of alumina or similar cutting agents.

After polishing, the specimens should be etched. If electrolytic polishing has been used, etching can normally be carried out with the same apparatus. Alternatively, and always where mechanical polishing has been used, the specimens should be etched in a 3% solution of picric acid in alcohol, to which has been added 3% of concentrated hydrochloric acid. This solution has been specially selected because it has a slight staining effect on the cracks, thus making them easier to observe.

The heat-affected zones of the etched specimens should be examined with a good quality microscope.* All specimens should be examined at a magnification of ×500, and, where it is desirable, lengths of cracks should be measured by means of a suitable traversing stage with measuring scales fitted to the microscope. The specimens can generally be examined more satisfactorily with a bench instrument than a projection microscope, since the resolution obtained on a normal ground glass screen is not always adequate.

In critical cases, and where variability of results suggests that some of the cracks are not being detected, the specimens should be re-examined at a magnification of ×1250. This re-examination at high power should be carried out on a proportion of the specimens from all small fillet welds ($\frac{5}{16}$ in. leg length and smaller). A typical crack is shown in Fig. 8.

* Magnetic or penetrant methods of crack detection can be used to avoid the need for microscopical examination of specimens with large cracks. Specimens in which no cracks have been revealed by these methods must still be examined under a microscope.

Arrangements for Co-operative Study

Materials were supplied from one source to the five co-operating laboratories. Two steels were selected for examination: the cast numbers and analyses of these are shown in Table I. The steels were selected so that they might be expected to show heat-affected zone cracks when welded with normal rutile-covered mild steel electrodes, but they were intended to show different degrees of weldability. Electrodes from one batch were also supplied to the five co-operating laboratories; these electrodes had mild steel core wires with a coating of class EXXXR1X (rutile). Electrodes for making the anchor welds EXXXB16 (basic) were also supplied. Basic electrodes were used for anchor welds since, with the steels used, it was known that these would give crack-free welds. Co-operating laboratories were asked to make duplicate test welds with thermal severity numbers 4, 6, 8 and 12 (*i.e.*, four CTS assemblies, two with both test plates 1 in. thick and two with test plates $\frac{1}{2}$ in. thick). Welding conditions which would give a weld with a leg length of a $\frac{1}{4}$ in. were notified to the various laboratories.

Table I

Analyses of steels examined

	Composition, %						
Cast No.	*C*	*Si*	*S*	*P*	*Mn*	*Ni*	*Cr*	*Mo*
O5593	0·21	0·07	0·043	0·026	1·62	—	—	—
Y4792	0·15	0·11	0·032	0·020	1·16	0·48	0·12	0·28

The laboratories were requested to section and examine the specimens, and to report the actual leg lengths of the welds, and the amount of heat-affected zone cracking, as a percentage of the appropriate leg length. The results from each laboratory were supplied to BWRA.

Results

The detailed results from the original examinations are shown in Tables II and III. From these results, an assessment was made for each steel of the highest thermal severity number at which the tests from each laboratory showed no cracks. These numbers are shown in Table IV, columns 2 and 4. With steel 05593, the agreement between the five laboratories was good, ranging from an estimate of 4 for laboratory *A*, to 6 for laboratories *C*, *D* and *E*, as the highest thermal severity at which the steel would not show cracks. For steel Y4792, however, three laboratories (*A*, *C*, *D*) showed good agreement, whilst the other two laboratories (*B* and *E*) agreed with each other, but at a considerably higher level of weldability than that found by the first three laboratories. In view of this discrepancy, it was decided to collect all the specimens at the laboratories of BWRA for re-examination by one metallographer.

There were several minor differences in the amounts of cracking observed by BWRA, as compared with those reported by the original laboratories. This was to be expected, since the re-polishing of the specimens might well expose a surface with a different crack length from that originally examined. This variation is not of great consequence, since the actual measurements of crack length are not very significant. On steel 05593, none of the differences found had any significant effect on the highest TSN at which the steel would be considered weldable, on the basis of the tests at each of the laboratories.

On steel Y4792 at TSN 12, laboratory *B* reported no cracking in any section of either weld. Re-examination at BWRA showed 18% and 8% cracking in the horizontal legs of two specimens from one of the welds. The same laboratory had reported no cracking with this steel at TSN 8, whereas BWRA found cracking in three out of six sections. The effect of this was to reduce the highest thermal severity number at which steel Y4792 would be considered weldable, on the basis of tests from laboratory *B*, from 12 to 7.

On this same steel, laboratory *E* indicated only small amounts of cracking in one leg of one section of one of the test welds at TSN 12; the examination at BWRA showed cracking in four out of six sections. Also on this steel, one section from the only test weld made by this laboratory at TSN 6 showed a small amount of cracking (5%), where the original laboratory had observed none. The effect of this is to reduce

Table II

Results of CTS Tests on steel O5593

(Electrodes BS.1719–E.219)

Laboratory	*TSN*	*Current, amp.*	*Arc voltage, V*	*Leg length, in.*		*HAZ cracking (% of leg length)*		
				H	*V*	*H*	*V*	*Av.*
A	12	170	19	0·27	0·26	19–24–32	24–19–42	27
A	12	173	19	0·26	0·26	30–37–69	0–23–32	32
B	12	175	22	0·25	0·23	7–21– 2	2–50–15	16*
B	12	175	22	0·26	0·26	16–16–22	0– 0– 6	10†
C	12	170	20–25	0·28	0·27	A– B– B	A– C– C	
C	12	170	20–25	0·27	0·26	0	0– A– C	
D	12	180	21	0·28	0·22	37–53–14	21–17– 0	24
D	12	185	21½	0·27	0·23	13–20–25	24–46– 0	21
E	12	170	22–24	0·23	0·28	10– 0– 0	33– 0– 0	7
E	12	170	22–24	0·21	0·27	8– 8– 0	10– 0–23	8
A	8	170	19	0·26	0·28	15– 0–76	16–12–15	22
A	8	170	20	0·26	0·26	20–10–10	19– 0– 0	10
B	8	170	21	0·25	0·24	25–37–19	0–13– 0	16*
B	8	170	21	0·26	0·24	39–47– 0	24–16– 0	21*
C	8	170	20–25	0·23	0·28	0– 0– B	A– C– A	
C	8	170	20–25	0·25	0·28	A– B– 0	0– B– B	
D	8	175	20½	0·33	0·21	48– 0–33	0	14
D	8	180	21	0·28	0·24	29–14–36	0–27– 0	18
E	8	170	22–24	0·21	0·28	0– 0–33	0– 0–17	8
E	8	170	22–24	0·22	0·30	0	0	0
A	6	175	19–21	0·29	0·22	56– 0–19	2– 0–10	15
A	6	175	19–21	0·28	0·24	0–17–21	24–26–22	18
B	6	175	22	0·21	0·25	0	0	0
B	6	175	22	0·24	0·26	0	0– 0–22	4
D	6	—	—	—	—	0	0	0
D	6	—	—	—	—	0	0	0
E	6	170	22–24	0·25	0·28	0	6–23– 0	5
E	6	170	22–24	0·26	0·28	0	0	0
A	4	175	19–21	0·27	0·27	0	0	0
A	4	175	19–21	0·27	0·26	16– 0– 0	0	3
C	4	170	21	0·25	0·22	0	0	0
C	4	170	21	0·22	0·28	0	0	0
D	4	—	—	—	—	0	0	0
D	4	—	—	—	—	0	0	0
E	4	170	22–24	0·23	0·29	0	0	0
E	4	170	22–24	0·26	0·30	0	0	0

* One section of three showed throat cracking. † All three sections showed throat cracking.

Note: Laboratory *C* did not measure the lengths of cracks, but recorded their magnitude qualitatively. The information supplied to B.W.R.A. has been assessed in four groups of crack severity: 0, A, B, C. 0 represents no cracking, and A, B, C represent increasing amounts of cracking.

Table III

Results of CTS tests on steel Y4792
(Electrodes BS.1719–E.219)

Laboratory	*TSN*	*Current, amp.*	*Arc voltage, V*	*Leg length, in.*		*HAZ cracking (% of leg length)*		
				H	*V*	*H*	*V*	*Av.*
A	12	170	21	0·28	0·27	0	0– 0–16	3
A	12	170	20	0·26	0·24	0– 0– 11	0– 0–16	5
B	12	170	21	0·25	0·32	0	0	0
B	12	170	21	0·25	0·31	0	0	0
C	12	170	20–25	0·27	0·27	A– 0– 0	0	
C	12	170	20–25	0·28	0·27	0– 0– A	0– 0– A	
D	12	175	20½	0·26	0·23	4–28– 0	0	5
D	12	180	21	0·27	0·22	44– 0–42	50– 0– 0	23
E	12	170	22–24	0·21	0·28	0	7– 0– 0	1
E	12	170	22–24	0·21	0·27	0	0	0
A	8	168	20	0·26	0·27	0	16– 0–17	6
A	8	170	20	0·29	0·27	0	17– 0–18	6
B	8	170	21	0·25	0·23	0	0	0
B	8	170	21	0·29	0·23	0	0	0
C	8	170	20–25	0·24	0·27	0– A– A	0	
C	8	170	20–25	0·25	0·27	0	0	
D	8	175	20½	0·29	0·23	59–23–61	0	24
D	8	180	21	0·31	0·23	34–33–40	0– 0– 7	19
E	8	170	22–24	0·24	0·33	0	0	0
E	8	170	22–24	0·23	0·31	0	0	0
A	6	175	19–21	0·32	0·23	0	0	0
A	6	175	19–21	0·28	0·25	0– 9– 0	0–33–34	13
B	6	175	22	0·24	0·30	0	0	0
B	6	175	22	0·24	0·26	0	0	0
D	6	—	—	—	—	0	0	0
D	6	—	—	—	—	0	0	0

Note: At TSN 4, tests were carried out by laboratories A, B, and D. No cracking was found.

Laboratory *C* did not measure the lengths of cracks, but recorded their magnitude qualitatively. The information supplied to B.W.R.A. has been assessed in four groups of crack severity: 0, A, B, C. 0 represents no cracking, and A, B, C represent increasing amounts of cracking.

the highest thermal severity at which the steel would be indicated as being weldable, on the basis of tests conducted by laboratory *E*, from 11 to a figure between 6 and a little over 8, which has been assumed to be 8. The complete results for the amount of cracking found by the original laboratory and by BWRA are shown in Tables V and VI.

Discussion and Conclusions

In considering the results of these tests, it should be remembered that the original restrained fillet tests were designed so that the results would be judged on the basis of the absence or presence of cracks; the lengths of the cracks were not considered. With the later development of the CTS test, in which the severity of cooling could be varied, it was at first thought that crack lengths had some significance, and that these could be used to provide sub-divisions of steps equivalent to changes of two units in the thermal severity number. However, the experience of the British Welding Research Association over a number of years shows that, in fact, the lengths of cracks obtained are not very significant. This indication has received further support from the tests reported here: whilst the highest thermal severity number at which each of the steels would be indicated as being weldable does not vary greatly between one laboratory and another, the lengths of cracks obtained do show considerable variation. Further, quite wide changes in reported crack length were sometimes found in the same specimens, examined at the laboratory of the organization making the test, and re-examined at BWRA. It should be emphasized therefore, that, whilst for certain research purposes there is value in measuring and recording the crack lengths, no great significance should be placed on them, and the criterion by which results of CTS tests should be judged should be the presence or absence of cracks.*

The results of the re-examination of the specimens by BWRA have shown that some experience is needed in detecting all the cracks. The operators at BWRA have been working on this subject for more than 5 years, whereas some of the co-operating laboratories were carrying out for the first time tests of the type described.

* Further experience may show that the criterion should not be the complete absence of cracks, but should be a positive limiting value; for example, not more than 5% of the weld leg length.

Table IV

Highest TSN at which each steel would be considered weldable

Laboratory	*Steel O5593*		*Steel Y4792*	
	Original Lab.	*BWRA*	*Original Lab.*	*BWRA*
A	4	4	5	5
B	5	5	12	7
C	6	—	6	—
D	6	4	6	6
E	6	6	11	8

Some of the discrepancies between the results obtained from the tests carried out in the five laboratories can probably be ascribed to variations in welding technique. Although it is difficult to illustrate the point, the overall impression from the examination of all the specimens was that the penetration of the welds from laboratory *E* was rather less than for the welds from the other laboratories. Also, the cracks observed in the specimens from laboratories *B* and *E* took the form of fine cracking systems, contrasting with the rather coarse cracks observed in the specimens from the other laboratories. Whether these observations are

Table V

CTS tests on steel O5593

(Electrodes BS.1719–E.219)

Laboratory	*TSN*	*HAZ cracking (% of leg length)*					
		Original Lab.			*BWRA*		
		H	*V*	*Av.*	*H*	*V*	*Av.*
A	12	19–24–32	24–19–42	26	0– 0– 5	16– 9–34	11
		30–37–69	0–23–32	32	25– 0–13	28–20–40	21
B		7–21– 2	2–50–15	16	22–15– 9	6–38–15	17
		16–16–22	0– 0– 6	10	11–37–12	0–23–12	16
C		A– B– B	A– C– C	—	11– 9– 2	7–14–29	12
		0	0– A– C	—	9– 0–18	0– 0–29	9
D		37–53–19	21–17– 0	24	53–39–45	17–12– 0	28
		13–20–25	24–46– 0	21	27–16–45	25–32– 0	24
E		10– 0– 0	33– 0– 0	7	10– 0– 0	5– 0– 0	3
		8– 8– 0	10– 0–23	8	5– 3– 0	5– 0–20	5
A	8	15– 0–76	16–12–15	22	19– 0–66	18– 9–14	21
		20–10–10	19– 0– 0	10	22– 0– 9	21–10– 8	12
B		25–37–19	0–13– 0	16	29–24–20	5– 4– 0	14
		39–47– 0	24–16– 0	21	24–32–23	20–17– 4	20
C		0– 0– B	A– C– A	—	17– 5– 8	9–24–18	13
		A– B– 0	0– B– B	—	39–29–30	12–12–20	24
D		48– 0–33	0	13	51–36–51	0	23
		29–14–36	0–27– 0	18	33–25–57	0–23–19	26
E		0– 0–33	0– 0–17	8	0– 0–33	15– 0–27	12
		0	0	0	0	0– 5– 5	2
A	6	56– 0–19	2– 0–10	14	33– 2–15	3– 0–10	10
		0–17–21	24–26–22	18	0–20– 7	23–25–14	15
B		0	0	0	0	0– 6– 0	1
		0	0– 0–22	4	0– X– 0	0– X– 6	2
C		Specimens not available					
D		0	0	0	9–25–12	0–20–23	15
		0	0	0	X– X– 0	X– X– 0	0
E		0	6–23– 0	5	0	0	0
A	4	0	0	0	0	0	0
		16– 0– 0	0	3	21– 7– 0	0	5
B		0	0	0	0	0	0
		0	0	0	0	0	0
C		Specimens not available					
		0	0	0	1– 0– 0	0	0
		0	0	0	0	0	0
E		0	0	0	0	0	0

X Specimen not available to B.W.R.A.

Table VI

CTS tests on steel Y4792

(Electrodes BS.1719–E.219)

		HAZ cracking (% of leg length)					
		Original lab.			*BWRA*		
Laboratory	*TSN*	*H*	*V*	*Av.*	*H*	*V*	*Av.*
A	12	0	0– 0–16	3	25– 0– 5	2– 0–10	7
		0– 0–11	0– 0–16	4	7– 0– 8	0– 4–10	5
B*		0	0	0	0	0	0
		0	0	0	0–18– 8	0	4
C		0– 0– A	0	—	11– 4– 2	0– 4– 2	4
		0– 0– A	0– 0– A	—	6– 0–15	4– 0– 4	5
D		4–28– 0	0	5	28–24–14	0– 2– 0	11
		49– 0–42	50– 0– 0	23	42– X–27	17– X– 0	22
E		0	7– 0– 0	1	5– 2– 5	6– 0– 0	3
		0	0	0	9– 0– 0	0	2
A	8	16– 0–17	0	5	22– 0–21	0	7
		17– 0–18	0	6	20– 0–15	0– 4– 0	7
B		0	0	0	0	0	0
		0	0	0	7– 5– 0	0– 0– 2	2
C		0– A– A	0	—	17– 3– 6	0– 0– 1	4
		0	0– 0– A	—	0– 2– 0	0	0+
D		59–33–61	0	24	56–47–54	0	26
		34–33–40	0– 0– 7	19	X–17– X	X– 0– X	9
E		0	0	0	0	0	0
		0	0	0	0	0	0
A	6	0	0	0	0– 0– 7	0	1
		0– 9– 0	0–33–34	13	0	0–32–30	10
B		0	0	0	0	0	0
		0	0	0	0	0	0
D		0	0	0	12– X–20	0– X– 0	8
		0	0	0	0	0	0
E		0	0	0	5– 0– 0	0	1

X Specimen not available to B.W.R.A.

* Laboratory *B* re-examined its specimens, and the new results agreed with the B.W.R.A. assessments.

related to the lesser amounts of cracking in the welds made by laboratories *B* and *E* is not known.

Nevertheless, the agreement found between the results of tests carried out on the same materials by five laboratories is considered to be satisfactory.

It is the opinion of the Sub-Commission that the CTS test is satisfactory for scientific investigations of the phenomena associated with heat-affected zone cracking.

The test may also be used as a comparative test for steels, electrodes, and welding procedures.

However, extreme care was necessary to obtain the results given in this report, and some differences between laboratories still exist. For this reason the test cannot be used for specification or acceptance purposes.

The work of the Sub-Commission on the general problem of the weldability of steels as related to transformation phenomena in the heat-affected zones is continuing; the next stage is to be the collection of information relating results of CTS tests to service experience in welding low alloy steels.

REFERENCES

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REPORT OF COUNCIL FOR 1958

The Thirty-sixth Annual Report of the Council on the activities of the Institute during the twelve months ended 31st March 1958, was submitted for the approval of members at the Annual General Meeting on 16th July, 1959. 489

ANNUAL REPORT

Honorary Officers and Council

The Honorary Officers and Council elected in 1958 took office after the Annual General Meeting of 17th July 1958. Mr. John Strong delivered his Presidential Address to members at the opening of the Autumn Meeting in London on 6th November, 1958. The Address was printed in the *Journal* for December, 1958.

In March, 1959, Mr. A. C. Hartley, C.B.E., who had undergone a major operation in the Autumn, tendered his resignation of the Vice-Presidency. The Council accepted his resignation with regret, expressing the hope that after his term of office as President of the Institution of Civil Engineers he might be able again to consider accepting office in the Institute.

Expansion of Services

The year under report is the first full year under the revised Constitution approved at Extraordinary General Meetings in February and July 1958. It has been in the main a period of consolidation, in which effect has been given to the Future Policy outlined by the Council, the main feature of which is the expansion of the services rendered to members and to the engineering industry. Expansion has been most notable in Meetings, Publications, and the School of Welding Technology, while in other fields, and especially in the work of the Technical Committees and the Library, good progress has been made in resuming activities temporarily suspended and reorganizing for a further advance.

An Appeal to Industry for increased financial support to which detailed reference is made below brought over £9,000 in donations and promises and enabled the Council to repay half the sum borrowed on mortgage for the purchase of the house and to discharge certain outstanding liabilities for its conversion and repair.

Meetings

The Spring Meeting was held at Harrogate in association with the Leeds and District Branch from 7th to 10th May, 1958. The attendance was a little smaller than at previous Spring meetings but a useful and interesting programme of works visits was arranged and the papers presented at the technical sessions evoked good discussion.

The Autumn Meeting was held in London as usual in November, opening with the Annual Dinner at the Park Lane Hotel, the attendance at which, 390, was a record. The principal guest was Mr. W. J. Taylor, Parliamentary Secretary to the Ministry of Supply, who kindly took over from the Minister, Mr. Aubrey Jones, at very short notice. The technical sessions on the two following days were very well attended and the discussion on the seventeen technical papers presented in four sessions was most satisfactory.

The Second Annual Lecture was given by Dr. A. B. McIntosh, on behalf of Sir Leonard Owen, at the Institute on 12th March, 1959, the subject being "Welding and the Nuclear Energy Programme" (see *Journal* for May, 1959). The Institute's lecture hall was well filled.

On 24th September, 1958, a large audience gathered to hear a lecture by Mr. D. L. Pratt, Engineer of the Trans-Antarctic Expedition, on "Welding in Low Temperatures". The lecture, which was illustrated by a film and a large number of coloured slides, was enthusiastically received.

Two joint meetings were held during the year. On 28th October, at the Institution of Mechanical Engineers, a Joint Symposium on Aluminium Pressure Vessels attracted an enrolment of nearly 500; this symposium was organized in association with the British Welding Research Association, The Aluminium Development Association, The Institution of Mechanical Engineers, and The Institution of Chemical Engineers.

A joint meeting with the Iron and Steel Institute was held at the Institution of Naval Architects on 10th December, 1958. Mr. P. D. Blake presented four papers and Dr. Christensen two on different aspects of the problem of hydrogen in weld metal. All the papers had been pre-printed in the *Journal*, in which the valuable discussion will also appear.

During the year the Programme and Publications Committee, in common with all the Standing Committees of Council, has been considering how best to give effect in its own sphere to the Outline of Policy issued by the Council in 1957. The report has not yet been completed but one decision will have become known to members before this report is issued, namely, that the Spring Meeting will in future be held in London in alternate years during the Engineering, Marine, Welding and Nuclear Energy Exhibition.

Publications

In July, 1958, the Institute resumed direct responsibility for the editing and production of the *British Welding Journal*. This work is now undertaken for the Institute by Editech, one of the Partners of which is Mr. C. R. Harman, who acts as Executive Editor of the *Journal*. Changes in contents and presentation planned in the previous year have been introduced gradually and further improvements are intended, with the object of enlarging the *Journal* and widening its technical appeal. It has been decided in July to resume control of the advertisements so that the administration of the *Journal* will be fully integrated under the general editorship of the Secretary.

During the year the Institute published the proceedings of the First Commonwealth Welding Conference and a combined *Index to the Transactions of the Institute of Welding and Welding Research*, for the years 1938 to 1953. The first of these publications was sold out by the end of the year.

The Health and Safety booklet also went out of print during the year, having sold 25,000 copies in less than three years.

A list of the Honorary Officers and Council for 1958–59 appears on p. 17 of this issue (Advert Section).

Volume 2 of the *Handbook for Welding Design* has been delayed for lack of two or three sections and the resignation of the compiler has postponed the completion of Volume 3. The Programme and Publications Committee is giving urgent consideration to finishing this long awaited work of reference.

Education Committee

The Education Committee continued to carry out its routine work: it dealt with enquiries and requests for assistance in connection with welding courses from eleven different technical colleges; it advised the British representatives on the Welding Instruction Commission of the International Institute of Welding, and it organized the Institute's own examinations. As regards the last point, machinery has been established for the oral examination of candidates eligible, under the revised membership regulations, to qualify in this way for Associate-Membership.

The Education Committee has been increasingly concerned about the need for refresher courses in welding for teachers. On its initiative, a course for teachers of engineering up to H.N.C. level is being organized this year at the Manchester College of Technology, while the Institute's School of Welding Technology is planning to hold in 1960 a course for teachers of welding for the City and Guilds of London Institute examinations.

A careful study has been made during the year of those aspects of the Council's Outline of Policy which fall within the province of the Education Committee; a number of detailed recommendations were submitted to and approved by the Council.

School of Welding Technology

The School has now completed its first eighteen months of service to the British engineering industry. In that time more than 1,000 engineers, designers, and draughtsmen have attended the courses, day and evening, offered by the School. The demand for places is such that it was decided from January, 1959, to organize two day courses a month instead of one. The following is a list of courses held during the year with the attendances:

Day Courses

1958	April	D. 8	Welded Structures	39
	April	D. 9	Health and Safety	33
	May	D. 7	Ultrasonic Inspection	52
	June	D. 11	Inert-Gas Arc Welding	40
	Oct.	D. 12	Control of Distortion	48
	Oct.	D. 13	Residual Stresses	42
	Nov.	D. 10	Welding in Shipbuilding	35
	Dec.	D. 5/1	Inspection and Testing	40
1959	Jan.	D. 23	Training, Testing and Approval of Welders	28
	Feb.	D. 15	Brazing Technology and Design	39
	Feb.	D. 16	Welded Storage Tanks	25
	Mar.	D. 6/1	Welded Design and Construction in Corrosion and Heat-Resisting Materials	30
	12 day courses			451 students (average—37 per course)

Evening Courses

1958	E. 1/4	Detail Design of Welded Structures	120 (approx.)
	E. 1/5	Detail Design of Welded Structures	117
			237 students

The maximum enrolment for a day course is normally 40.

The management of the School is entrusted to a standing committee of Council with Mr. E. Seymour-Semper as Chairman. Courses are now planned for two years ahead, and the committee gives much thought to long-term development of a project which is already an outstanding achievement for a technical institute. The Council has approved proposals for the establishment of an Advisory Council on Welding Education, on which it is intended to invite representatives of government departments, industry and educational authorities to serve.

Sir William J. Larke Medal

The Sir William J. Larke Medal for 1957 was awarded to Mr. M. Noone and Mr. W. C. Holliday, for their paper on "Welding of Spheres and Bullets *in situ*". The Medal was presented to the winners at the Spring Meeting at Harrogate.

Technical Committees

Most of the technical sub-committees and panels have met again after a period of enforced suspension. The projects in hand have been examined afresh and various plans for the re-organization of the work have been under consideration, the primary object being to formulate a programme which the technical staff can carry through punctually and effectively. This will necessarily entail the establishment of a series of priorities, particularly in respect of the various projects involving the compilation and publishing of booklets, on which several of the panels are engaged.

A technical committee on Inspection and Testing has been set up to carry on the work of the B.W.R.A. Non-Destructive Testing Committee and preparations have been made for the establishment of a committee on Metal Spraying in view of the extension of the Institute's interests into this field.

The main Technical Committee and several of its sub-committees advise British delegates on the I.I.W. Commissions and sub-Commissions, the work of which is increasing with the growing activity of I.I.W.

Another most important function of the Technical Committee is the appointment and briefing of Institute representatives on the committees of the British Standards Institution. The procedure for commenting on draft standards has been under review as part of the re-organization mentioned.

Library and Information Service

Miss W. R. Urwin, A.L.A., the Library Assistant, has had to deal with very considerable arrears of work, due to the double removal of the Institute in 1956 and 1957 and to the illness of her predecessor. Various lists have been revised and a number of improvements both in the equipment and in the organization of the library service has been effected. The service has made an encouraging recovery over the past year and the number of members using it is now higher than for many years. During the year 480 borrowers were lent 1,037 items, whilst written enquiries averaged twenty a week and telephone enquiries about twenty-five a week.

The Library Assistant compiles the contents lists of welding periodicals published in the *British Welding Journal* and also supplies the abstracts of British welding publications for the *Bibliographical Bulletin for Welding and Allied Processes*. The number of abstracts supplied last year was 313—a big service to British welding.

Miss Urwin is also responsible for the selection and despatch of British welding publications for display at the I.I.W. Annual Assembly.

Branches

All the Branches remained active throughout the year and held full programmes. Several of the Branches organized meetings aimed at attracting new members either from

THE INSTITUTE OF WELDING

BALANCE SHEET, 31st MARCH, 1959

31.3.58		£ s. d.	£ s. d.
£	*Accumulated Fund*—		
	Balance as at 31st March, 1958	21,113 14 8	
	Add Transfer from Working Reserve Fund	4,733 11 2	
		25,847 5 10	
	Add Excess of Income over Expenditure ..	281 2 1	
21,114			26,128 7 11
	Provisions and Current Liabilities—		
600	Premises Repairs and Renewals	600 0 0	
600	Reserve for Publications	600 0 0	
130	Furniture and Equipment Renewals Fund (transferred to Furnishing and Mortgage Redemption Fund)	—	
1,644	Overdraft at Bankers (Secured by a charge on Investments)	7,980 4 9	
8,168	Sundry Creditors and Credit Balances ..	4,189 11 1	
435	Subscriptions, Entrance and Examination Fees received in advance	381 19 2	
11,577			13,751 15 0
	Loan on Mortgage (Secured by a charge on Freehold Property)		
	Balance as at 31st March, 1958	10,000 0 0	
	Less Amount repaid to date	5,000 0 0	
10,000			5,000 0 0
	British Welding Journal—		
3,355	Subscriptions in Advance		2,996 17 10
	School of Welding Technology—		
3,263	Fees and Deposits in Advance		1,385 19 1
	Appeal Funds—		
891	"Services to Industry" Fund		7,245 17 8
	Furnishing and Mortgage Redemption Fund		
	Contributions to 31st March, 1958 ..	988 7 9	
	Add Transfer from Furniture and Equipment Renewals Fund	130 0 9	
	Income for the year to 31st March, 1959 ..	180 2 3	
		1,298 10 9	
	Less Cost of special furnishings and fittings purchased	1,046 5 2	
489			252 5 7
	Special Funds—		
87	Sir William Larke Medal Fund	89 11 7	
275	C. W. Hill Prize Fund	286 12 7	
276	Life Membership Subscription Fund ..	305 19 9	
—	Tibbenham Trust Fund	111 16 6	
	Mortgage Redemption Sinking Fund—		
	Balance 31st March, 1958 £1,429 15 6		
	Add Income for year to 31st March, 1959		
	Interest on Investments 33 6 6		
	Transfer from Income and Expenditure A/c. 250 0 0		
1,430		1,713 2 0	
2,068			2,507 2 5

31.3.58		£ s. d.	£ s. d.
£	*Fixed Assets*—		
	Freehold Property, 54 Princes Gate, S.W.7, at cost	40,090 13 7	
40,090	*Less* Depreciation written off	700 0 0	39,390 13 7
	Furniture and Fittings at cost *less* sales ..	3,858 17 4	
2,319	*Less* Depreciation written off to date ..	1,089 18 7	2,768 18 9
	Council Room Furniture at cost	409 4 6	
42	*Less* Donations received	363 18 3	45 6 3
	Special Furniture and Fittings at cost ..	1,046 5 2	
—	*Less* Provided out of Furnishing and Mortgage Redemption Fund	1,046 5 2	—
42,451			42,204 18 7
	Current Assets—		
63	Stock of Publications	1,305 19 9	
3,287	Investments in Government Securities at cost (Market Value 31.3.59 £5,499) ..	6,221 16 8	
2,556	Sundry Debtors and Payments in Advance	5,498 0 1	
986	Expenditure on Handbook for Welding Design—*less* Contribution and Sales ..	610 16 11	
1,346	Cash at Bankers and in Hand, Head Office and Branches	919 11 1	
8,238			14,556 4 6
	Special Funds (Investments and Cash at Bankers)—		
87	Sir William Larke Medal Fund	89 11 7	
275	C. W. Hill Prize Fund	286 12 7	
276	Life Membership Subscription Fund ..	305 19 9	
—	Tibbenham Trust Fund	111 16 6	
	Mortgage Redemption Sinking Fund—		
	Investments in Government Securities at cost (Market		
824	value 31.3.59 £731) .. £823 14 7		
606	Cash at Bank 889 7 5		
		1,713 2 0	
2,068			2,507 2 5
	Working Reserve Fund—		
4,684	Investments and Cash at Bank 31.3.58 ..	4,683 18 7	
	Income six months to 30th September, 1958	49 12 7	
		4,733 11 2	
	Less Transferred to Current Assets ..	4,733 11 2	—

31.3.58		£ s. d.	£ s. d.
	Working Reserve Fund—		
	Balance at 31st March, 1958	4,683 18 7	
	Income six months to 30th September, 1958	49 12 7	
		4,733 11 2	
4,684	*Less* Transfer to Accumulated Fund ..	4,733 11 2	—
£57,441			£59,268 5 6

31.3.58		£ s. d.
	J. STRONG, *President*	
	W. E. HARRISS, *Treasurer*	
	G. PARSLOE, *Secretary*	
£57,441		£59,268 5 6

REPORT OF THE AUDITORS TO THE MEMBERS OF THE INSTITUTE OF WELDING

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purpose of our Audit. In our opinion, proper books of account have been kept by the Institute so far as appears from our examination of those books. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account. In our opinion and to the best of our information and according to the explanations given us, the said Accounts give the information required by The Companies Act, 1948, in the manner so required, and the Balance Sheet gives a true and fair view of the state of the affairs of the Institute as at 31st March, 1959, and the Income and Expenditure Account gives a true and fair view of the income and expenditure for the year ended on that date.

21 Godliman Street, London, E.C.4.
19th June, 1959.

GORDON EVANS & CO.,
Chartered Accountants.

THE INSTITUTE OF WELDING

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1959

1958		£ s. d.	£ s. d.
£	*Administrative Expenses*—		
6,482	Salaries	7,008 17 9	
486	Superannuation	540 4 0	
75	Pension	200 0 0	
693	Travelling Expenses	630 3 1	
70	Entertaining	161 15 0	
1,387	Printing and Stationery	1,378 11 9	
474	Postages	660 19 2	
66	Sundry Expenses	57 17 1	
367	Legal and Professional Fees	57 15 0	
110	Audit Fee	157 10 0	
650	Interest on Mortgage and Bank Overdraft	624 18 5	
10,860			11,478 11 3
	Establishment Expenses —		
1,379	Rent, Rates, Lighting, Heating, Cleaning, *less* Rents received	1,010 13 6	
569	Telephone	363 19 5	
73	Repairs and Decorations	1,211 4 0	
258	Depreciation (Furniture, Fittings) ..	307 13 2	
—	Depreciation (Property, 54 Princes Gate)	700 0 0	
241	Removal Expenses and Storage Charges ..	—	
500	Mortgage Redemption Sinking Fund ..	250 0 0	
3,020			3,843 10 1
	Direct Service to Members—		
2,766	Publications *less* Sales	1,597 16 3	
1,797	Library and Information Services ..	2,183 2 1	
2,240	Branch Expenditure	2,366 3 7	
93	Hire of Rooms and Meeting Expenses ..	404 13 4	
136	Examination Expenses	139 1 9	
256	Subscriptions to Scientific Societies ..	283 11 1	
7,288			6,974 8 1
—	Balance—Excess of Income over Expenditure transferred to Accumulated Fund		281 2 1
£21,168			£22,577 11 6

1958		£ s. d.
£		
18,199	Subscriptions	19,788 11 10
512	Entrance Fees	606 18 6
60	Examination Fees	135 12 2
152	Interest Received	239 19 1
1,050	Contribution from International Institute of Welding ..	1,525 0 0
928	School of Welding Technology and Special Courses ..	281 9 11
20,901		22,577 11 6
267	Balance—Excess of Expenditure over Income	—
£21,168		£22,577 11 6

a special section of industry such as Metal Spraying or from engineering students or draughtsmen. The success of these meetings should prompt other Branches to similar action planned with special reference to the industrial needs of their own areas.

Co-operation with Other Bodies

Regular consultation among the Officers ensures continuous co-operation between the Institute and the British Welding Research Association, the fruits of which are most evident in the development of the School of Welding Technology, which includes visits to the Research Association at Abington in many course syllabuses, and in the development of the *British Welding Journal*, the official organ of both the Association and the Institute.

In the summer of 1958 the International Institute of Welding marked the completion of its first ten years of growth and activity by the publication of a handsome commemorative volume *I.I.W./I.I.S. 1948–1958*. The Council of the Institute offers its congratulations to I.I.W. and takes satisfaction in the progress achieved and in the growing influence of the international organization, of which the Secretary of the Institute has been the Secretary-General since its beginning. Members of the Institute derive considerable benefit from this connection in respect of meetings and publications and through the Library and Information service.

Reference has already been made to joint meetings with other Institutions for the study of problems of common interest.

Membership

The total membership on 31st March, 1959, was 4,882, made up as shown in the table below, which gives the corresponding figures at the same date during 1956–58.

	1956	1957	1958	1959
Honorary Fellows	2	2	2	2
Patrons	12	12	12	12
Fellows	1	1	1	1
Honorary Members	14	14	15	14
Members	938	928	918	897
Associate Members	1,766	1,783	1,797 56	1,896
Companions	137	153	181	204
Graduates	137	142	156 73	206
Associates	1,156	1,216	1,269	1,311
Students	79	76	73 (now graduates)	
Overseas Members	62	59	56 (now Associate Members)	
Industrial Corporate Members				
Class 1	378	385		
Class 2	23	24	342	332
Class 3	8	7		
H.M. Forces Membership	6	6	7	7
	4,719	4,808	4,829	4,882
Annual Gain or Loss	+79	+89	+21	+53

The Council elected 289 (254) new members and approved 64 (28) transfers and 4 (2) reinstatements. During the year, 121 (86) members resigned and 95 (120) were removed from the register by the Council for non-payment of subscriptions.

The Council records with regret the death, on 22nd August, 1958, of Mr. W. H. Carslaw, who served as Chairman on the Institute's Membership Committee for many years. The Council regrets to record also the death of 23 (27) other members.

The figures in brackets are the corresponding figures for the year 1957–1958.

Premises

With the help of funds provided by members, and in particular the subscriptions to the Furnishing and Mortgage Redemption Fund, the Council has been able to make further progress with the adaptation and development of 54 Princes Gate, improving its convenience for the Institute's purposes. The London Branches continue to hold their evening meetings in the Lecture Hall, which is also used for meetings of the Institute, for Council and Committee meetings and for the courses of the School of Welding Technology. Several much appreciated gifts have improved the amenities and attractiveness of the Hall: the Council offers its thanks to the Past President, Sir Charles Lillicrap, for having the Institute's Grant of Arms framed for display; to the North London Branch Committee for the gift of the epidiascope; to the South London Branch Committee which presented a projection screen and a handsome oak cupboard; to Rockweld Ltd., who have kindly placed a film projector on permanent loan; to A.E.I. Lamp and Lighting Ltd., for the gift of specially designed electric light fittings; and to the South Wales Branch for the gift of two chairs for the Council Room suite. The furnishing of the room has been completed by the purchase from the Furnishing and Mortgage Redemption Fund of 22 chairs and 12 tables.

The Members' Room and the General Office on the ground floor have been changed over, to give more space to the former, in which light refreshments are served before meetings and during School courses.

Finance

Toward the end of the previous year the President, Sir Charles Lillicrap, and the then Vice-President, Mr. John Strong, addressed an appeal for increased financial support to Industrial Corporate Members. The response by the end of the year under report exceeded £9,000. Lists of the donations and subscribers have been printed in the *Journal*.

In the Income and Expenditure Accounts, for the first time since 1955/6, income for the year exceeded expenditure by £281, after providing £700 for depreciation of 54 Princes Gate and transferring £250 to the Sinking Fund for redemption of the mortgage. A reduction of £1,168 in the net cost of Publications, as compared with 1957/58, more than offset increases in all the other direct services to members. All sources of income, except the surplus on the School of Welding Technology, showed increased yields; the figures for Subscriptions and Entrance Fees, together £20,395 as against £18,711 in 1957/58, are particularly encouraging.

The Balance Sheet reflects the decision of the Council to merge the Working Reserve Fund in the Accumulated Fund, the repayment of half the mortgage loan of £10,000, and the establishment of the Tibbenham Trust Fund.

Acknowledgments

At the close of a fruitful year of progress the Council offers its thanks to all who have assisted the Institute, and in particular to the subscribers to the two appeal funds, to the lecturers in the School of Welding Technology, and to their employers, to the members of Committees and Sub-Committees, to the Honorary Officers and Committee Members of the Branches and finally to the Staff for loyal and effective service.

Welding
RESEARCH

B.W.R.A. REPORT

Further Tests on Welded Connections Between I-Section Beams and Stanchions

The work described in this report is concerned with the economical design of welded beam-to-stanchion rigid connections for multi-storey steel frames fabricated from material to BS.15. An earlier report contained details of similar tests carried out using rather small beam sections but it was considered that scale effect might be of some significance so this further series was undertaken with a somewhat more realistic size of beam. A total of sixteen specimens was fabricated and tested and their behaviour is illustrated by means of graphs which show the relationship between the applied moment and the deflection at certain specified points. In every instance the stanchion was a length of 10×8 in.×55 lb. RSJ, and the beams were all 16×6 in.×50 lb RSJ, but all the joints were different as regards details of construction, fabrication, and sizes of weld. The effects of these variations on the behaviour under test were studied and a list of recommendations has been drawn up for use in design. Fillet welds only were used throughout.

By

L. G. Johnson, M.A.,

A.M.I. STRUCT. E.

FRAME construction for multi-storey buildings, which relieves the walls of the task of carrying any but their own weight, has been established for half a century, but it is only recently that any real attempt has been made in Britain to depart from traditional methods of wall construction. Curtain walling has now been applied successfully to a number of projects and it is possible that the time will come when it is specified for all new tall buildings. Any multi-storey structure which has some form of light pre-fabricated cladding differs from the traditional building in that it has to rely on its own skeleton, or alternatively a system of bracing, for its rigidity. Bracing itself is often undesirable for practical reasons, except perhaps round lift shafts where it causes no real obstruction, and it seems inevitable that there will be an increasing demand for fully rigid building frames. The conventional steel frame which utilizes simple black bolted stool and top cleat connections is quite inadequate. Such frames are designed by the orthodox methods which date back to the beginning of the century. The method of proportioning stanchions is irrational and beams are assumed to be simply supported, with reactions acting at not more than 2 in. from the face of the column; yet the Steel Structures Research Committee's tests on buildings showed that in most cases the eccentricity is nearer twenty times that distance. Conventional design of lightly clad multi-storey frames leads to sections, and particularly connections, which are quite unsuitable from considerations of both strength and deflection. The frame must of necessity be rigid in itself to prevent excessive deflection with the possibility of sway oscillation under wind. Any deflection which does occur should be mainly elastic.

These facts call for rigid beam-to-stanchion connections and this in turn precludes the use of compound stanchions, owing to the difficulty of transferring forces from the flange plate to the joist. Furthermore,

Report D1/7/58 of the British Welding Research Association, issued to members in March 1959.

Mr. Johnson, formerly in the Department of Engineering at Cambridge University, is the General Manager of The Skeleton Steel Co. Ltd., Stratford-on-Avon.

the web of a rolled steel section is comparatively thin and has to be stiffened locally to resist the applied moments. Such local stiffening can often complicate the erection of the secondary beams but ways can be found to overcome this difficulty.

The only really satisfactory way of obtaining full strength beam-to-stanchion connections is by welding. Shop welding is now commonplace but many engineers are still reluctant to use site welding no matter what advantages it may offer in particular instances. The availability of a simple non-destructive method of weld testing would no doubt do much to overcome this prejudice but this is a problem which does not seem to have an easy solution.

It has to be remembered that a steel frame that is to be site welded must first be temporarily fastened together during erection. This initial positioning of the members is not satisfactorily achieved by means of welding, and bolts or clamping devices, which do not usually contribute to the ultimate strength of the structure, have to be used. Such clamps or bolts should be kept to a minimum and preferably be allowed to remain permanently in position after welding because much time and effort can be wasted in removing them. Site welding involves the use of some form of scaffolding and possible wind shields, and the work will need to be subjected to very close and frequent inspection. Welding is still comparatively expensive, and to be competitive all joints must be very carefully designed to use the minimum amount of weld metal and to ensure that as much of it as possible is done in the downhand position.

The theoretical and practical requirements which must be satisfied by rigid beam-to-stanchion connections in a structure designed by the plastic theory have been set out in a previous paper* and will not therefore be repeated here.

Experimental Work

The sixteen specimens that were tested can be divided into three groups:

Group 1: *Specimens A and B.* These were in the nature of pilot tests, which were carried out to check the suitability of the basic design of the joint. They were fabricated at the Cambridge University Engineering Laboratory Workshops.

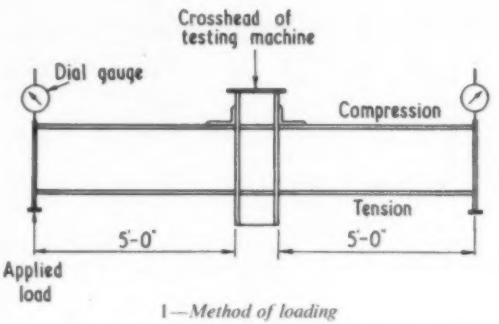
Group 2: *Specimens* 1 *to* 7. This batch of seven test pieces was fabricated by a steelwork contractor under normal workshop conditions.

Group 3: *Specimens* 8 *to* 14. These too were made under workshop conditions but by a different company.

All the connections consisted of a 2 ft 6 in. length of 10 × 8 in. × 55 lb RSJ, and two 5-ft lengths of 16 × 16 in. × 50 lb RSJ with 6 × 4 × ½ in. angle stool cleats. The specimens were welded into a symmetrical cruciform shape (see Figs. 2–5). A diagrammatic representation of the method of load application and deflection measurement is shown in Fig. 1. (The position of the joint in the testing machine is upside down relative to the position it would occupy in an actual structure.) Fabrication details of all the joints are shown in Figs. 2–5.

Loads were applied by a 500-ton Amsler hydraulic compression-testing machine, using a beam table to give two-point support to the specimens. The loads were measured directly from the machine and deflections were recorded by simple dial gauges to an accuracy of 0·001 in. Every joint and the adjacent areas were given a coating of plumber's resin so that the attainment of the yield stress and the position of local yielding could be noted.

The point loads were applied at a distance of 5 ft from the face of the stanchion. A plate was welded to the outer end of each beam so as to prevent twisting during test, the plates themselves sitting on a roller which in turn was mounted on the beam table. Figure 6 shows the relationship between the applied moment and the deflection of the beam, due to bending only, at the point of application of the load. The deflection due to shear has been estimated and is deducted from the observed total.



1—*Method of loading*

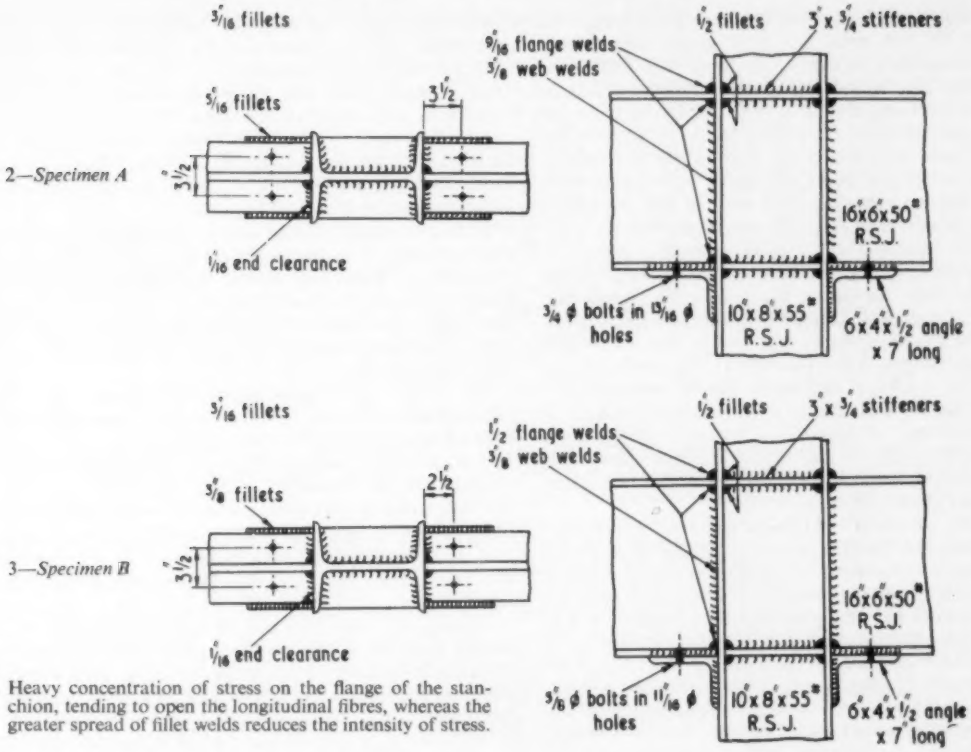
All the specimens were basically similar in design but certain details were changed in each of them so that the effects of these variations might be studied. For example, the clearance between the end of the beam and the face of the stanchion was in some cases ⅛ in., in others 1/16 in. and a few had no clearance at all. Weld sizes and stiffener thicknesses too were not kept constant, and specimens 8–14 had certain stiffeners which were deliberately made a rather slack fit. The specified end clearances were maintained by small shims inserted between the beam and the face of the stanchion. Under normal site conditions shims would not be necessary because both ends of the beam could be securely positioned by first welding the flanges to the stool cleats.

All the connections were fabricated under normal workshop conditions, the welding being carried out by a competent craftsman. Specimens 1–7 were welded in the position they would actually occupy on site, *i.e.* the webs of the beams were in the vertical position and the underside of the tension flanges were in the overhead position. The electrodes used were to BS.1719 Classification E217, E317, and E319.

Fillet welds were used in preference to butt welds for connecting the flanges of the beam to the face of the stanchion, because the single-V butt weld is generally regarded as inferior to the fillet weld for the following main reasons:

1. It is difficult to make and requires preparation of the beam flanges
2. The quality of the weld depends to some extent on the end clearance of the beam, a dimension which cannot be guaranteed under normal workshop and site conditions
3. Lack of penetration into the flange of the stanchion

* L. G. JOHNSON: *Brit. Welding J.*, 1959, vol. 6, pp. 38–46.



4. Heavy concentration of stress on the flange of the stanchion, tending to open the longitudinal fibres, whereas the greater spread of fillet welds reduces the intensity of stress.

The variations in end clearance from zero to $\frac{1}{8}$ in. were an attempt to simulate site conditions, for the normal structural tolerance of $\frac{1}{16}$ in. cannot be guaranteed because of such factors as over-rolling of the stanchions and inaccuracies in measurement.

The few weld failures which did occur were all near a tension flange and happened at moments which were always appreciably greater than the full plastic moment of the beam, based on a yield stress of 15·25 tons/sq.in. It is more than likely that most of these weld failures would not have occurred if the absence of lateral support had not led to twisting and secondary bending action about the minor axis of the beams at the later stages in the tests. This secondary bending undoubtedly resulted in more critical loading conditions than would have been allowed to develop in an actual structure.

Test Results

Group 1: Specimens A and B (Figs. 2 and 3)

These two preliminary tests were carried out to determine the general suitability of the beam-to-stanchion connection and the efficiency of the test rig.

Specimen *A* had $3 \times \frac{3}{4}$ in. web stiffeners, *i.e.*, each approximately equal to the area of one half of the flange of the beam, and they were cut to shape by a profile burner. No attempt was made to achieve a perfect fit by careful fitting and machining. On the compression side the stiffeners were fixed in position by continuous $\frac{3}{16}$ in. fillet welds but on the tension side the stiffener-to-flange welds were increased to $\frac{1}{2}$ in. fillets. The angle cleats were attached to the stanchion by $\frac{3}{16}$ in. fillet welds. The beams were bolted to the cleats and there was $\frac{1}{16}$ in. end clearance which was maintained during welding by means of small shims. The flange-to-stool cleat welds were $\frac{5}{16}$ in. fillets, web-to-stanchion welds $\frac{3}{8}$ in. fillets, and flange-to-stanchion welds $\frac{9}{16}$ in. fillets.

Specimen *B* was of the same basic construction, but there were a few small modifications. These were an increase in the size of the flange-to-cleat welds from $\frac{5}{16}$ in. to $\frac{3}{8}$ in., a decrease in the flange-to-stanchion welds from $\frac{9}{16}$ in. to $\frac{1}{2}$ in., and a reduction in the diameter of the securing bolts from $\frac{3}{4}$ in. to $\frac{5}{8}$ in.

The moment/deflection curves shown in Fig. 6 are in close agreement throughout, and both joints proved themselves capable of transmitting appreciably more than the theoretical full plastic moment of the beam section. This value was exceeded by 28% by specimen *A*, and 24% by specimen *B*. These moments were accompanied by deflections of the order of $\frac{7}{8}$ in. Both tests ended in the failure of one of the tensile welds in precisely the same way as in the previous series, *i.e.*, the initial fracture started in the web-to-stanchion weld about 1 in. away from the root fillet of the beam, the crack then spreading along the inner flange weld and finally across the outer tension flange weld. It was therefore decided to modify the design of future specimens to overcome this tendency by continuing the tension flange weld down the web for a distance of 3 in., as shown in Figs. 4 and 5. This small additional amount of weld metal was later found to be sufficient to prevent any recurrence of premature weld failure in the region of the root fillet.

The moment/deflection relationships during the early part of the tests are very good indeed and approximate closely to that of the ideal rigid joint. It is not until the theoretical full plastic moment has been reached and passed that any real departure from an almost linear characteristic is noticed. A certain amount of yielding was observed in the web stiffeners, those on the compression side being affected a little earlier than those on the tension side. The web of the stanchion showed little evidence of yield even at maximum load. The beams behaved entirely as expected, however, yield commencing firstly in the extreme fibres of the flanges and then spreading inwards until almost the whole of the web was stressed beyond the elastic limit.

From the shape of the curves in Fig. 6 it is obvious that plastic hinges were formed at the ends of the beams. The $6\times4\times\frac{1}{2}$ in. angle cleats undoubtedly stiffen the beams but this is an advantage because it means additional strength. As has previously been pointed out though, the real function of the cleats is to facilitate erection and their stiffening effect is not taken into account in the calculations.

When the moment was increased beyond about 1400 in. tons the specimens began to buckle slightly. That is to say the stanchion tended to twist, moving the inner ends of the beams horizontally and in opposite directions; the general effect being for the beams to take up the shape of a very elongated letter **S** No practicable method of preventing this could be found, but such buckling action about the minor axis of the beams must mean that additional and indeterminate stresses are superimposed on an already highly stressed specimen. In an actual building frame the presence of secondary beams and a floor system would prevent such tendencies, but in any event this effect appears to have significance only at moments in excess of the theoretical full plastic value.

Following upon the success of these two tests it was decided to proceed with a further fourteen specimens.

Group 2: Specimens 1–7 (Fig. 4)

All the specimens were fabricated by the same steelwork contractor in a structural workshop under quite normal factory conditions. The web stiffeners were $3\times\frac{3}{4}$ in. section with $\frac{5}{16}$ in. fillet welds all round on the compression side but with the stiffener-to-flange welds increased to $\frac{1}{2}$ in. fillets on the tension side. These stiffener details were identical for all seven specimens. Every single joint was different, however, but the variations were only in the actual beam-to-stanchion connection itself. The end clearance varied from zero to $\frac{1}{8}$ in., the web welds from $\frac{5}{16}$ to $\frac{7}{16}$ in. fillets, and the flange welds from $\frac{7}{16}$ to $\frac{5}{8}$ in. fillets, the various combinations being shown in Fig. 4.

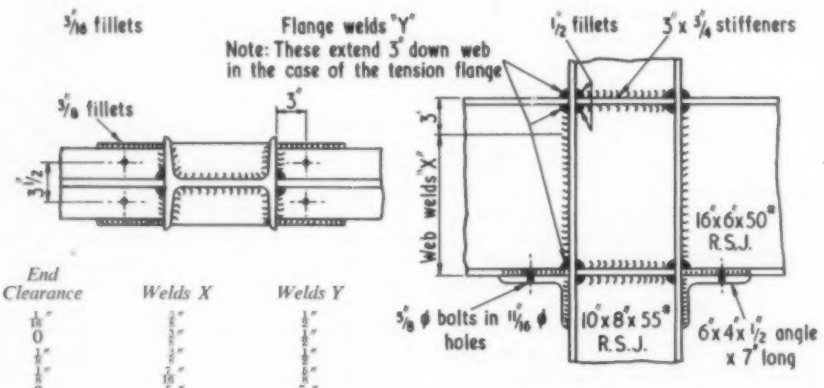
Fundamentally, these seven specimens were the same as the preliminary specimens *A* and *B*. The basic principles of using fillet welds, stool cleats, and simple plate stiffeners were employed, the object being to determine the effects of variations in the beam-to-stanchion connections, keeping the web stiffeners uniform throughout.

The only significant change in design was the addition of weld metal to the web at the tension flanges, which has already been referred to.

It must be emphasized that these beam-to-stanchion connections were welded under site conditions, *i.e.*, the web welding was done in the vertical position and the inside of the tension flanges in the overhead position, all other welding being downhand. In other words the fabrication was carried out as realistically as possible.

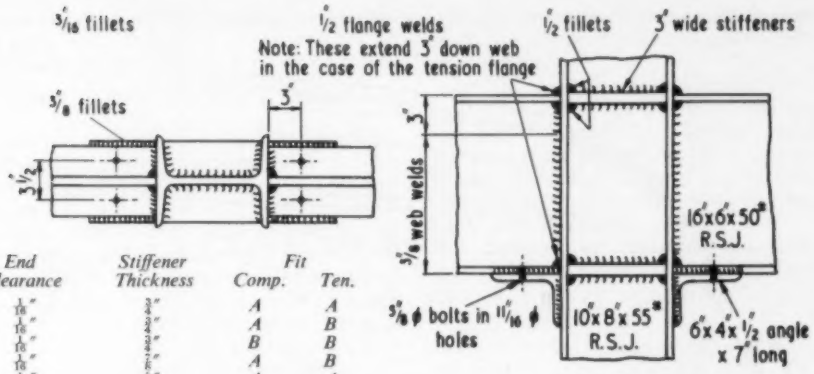
Testing revealed that all the joints behaved in a similar manner, giving results in close agreement. The moment/deflection curves plotted in Fig. 6 lie closely together, forming a narrow band which only begins to open out when the deflections exceed 0·6 in. The initial behaviour is extremely good and approximates closely to that of the ideal rigid joint, especially in the working range. Indeed even at the theoretical full plastic moment the deflections are only about 0·3 in., but as soon as the plastic hinges form there are big increases in deflection for comparatively small additional moments.

It seems therefore that the material and standard of workmanship must have been uniform otherwise there would not have been such close agreement in the results. Secondly, the variations in weld size and end clearance do not appear to have any appreciable effect on the overall rigidity of the joint but they do have some influence on the ultimate strength. Specimen 5



Specimen	End Clearance	Welds X	Welds Y
1	$\frac{1}{16}$"	$\frac{5}{16}$"	$\frac{1}{2}$"
2	0	$\frac{5}{16}$"	$\frac{1}{2}$"
3	$\frac{1}{8}$"	$\frac{5}{16}$"	$\frac{1}{2}$"
4	$\frac{1}{8}$"	$\frac{7}{16}$"	$\frac{5}{8}$"
5	0	$\frac{5}{16}$"	$\frac{7}{16}$"
6	$\frac{1}{16}$"	$\frac{5}{16}$"	$\frac{7}{16}$"
7	$\frac{1}{16}$"	$\frac{7}{16}$"	$\frac{5}{8}$"

4—*Specimens 1–7*



5—*Specimens 8–14*

Specimen	*End Clearance*	*Stiffener Thickness*	*Fit Comp.*	*Fit Ten.*
8	1/16"	3/4"	*A*	*A*
9	1/16"	3/4"	*A*	*B*
10	1/16"	3/4"	*B*	*B*
11	1/16"	5/8"	*A*	*B*
12	1/16"	5/8"	*A*	*A*
13	1/16"	5/8"	*A*	*B*
14	1/16"	5/8"	*B*	*B*

A denotes stiffener tightly fitted to web and flanges
B denotes stiffener with small clearance to flanges

was the only one to suffer a weld failure and this occurred at a moment of 1530 in. tons, which is 13% greater than the theoretical full plastic value.

This weld failure was not entirely unexpected because specimen 5 was one of the two joints with the minimum weld sizes of $\frac{5}{16}$ in. and $\frac{7}{16}$ in. fillets to the web and flange respectively. In general, it has been found that fillet welds with a throat area equal to the sectional area of the beam are able to transmit the full plastic moment. The fillet welds of specimen 5 were not equivalent to the section of the beam but they proved to be more than capable of developing the theoretical full plastic moment of the 16×6 in.×50 lb joist.

Specimen 6 was a reproduction of specimen 5 but with $\frac{1}{16}$ in. end clearance, and the joint proved to be entirely satisfactory. This might be accounted for by the extra weld penetration obtained by virtue of the $\frac{1}{16}$ in. clearance, but this fact cannot be firmly established by only two tests. What can be said, however, is that these weld sizes are the minimum necessary for developing the full plastic moment.

Group 3: Specimens 8–14 (Fig. 5)

This batch was fabricated by the second contractor, in the same conditions as specimens 1–7. In this series, the beam-to-stanchion connections were uniform throughout but the details of the stiffeners were varied. Every beam was given $\frac{1}{16}$ in. end clearance, as this was considered to be in line with normal structural fabricating practice, and the web and flange welds were fixed at $\frac{3}{8}$ and $\frac{1}{2}$ in. fillets respectively. The stiffeners were all 3 in. wide but with thicknesses ranging from $\frac{5}{8}$ to $\frac{7}{8}$ in. In addition, an attempt was made to determine the effects of using very loosely fitting stiffeners, which were made to touch the web but had a clearance of rather less than $\frac{1}{32}$ in. to the inside of the stanchion flanges. Full details are shown in Fig. 5. Unlike specimens 1–7, which were welded under site conditions, specimens 8–14 were rotated so that all the welds could be laid in the downhand position.

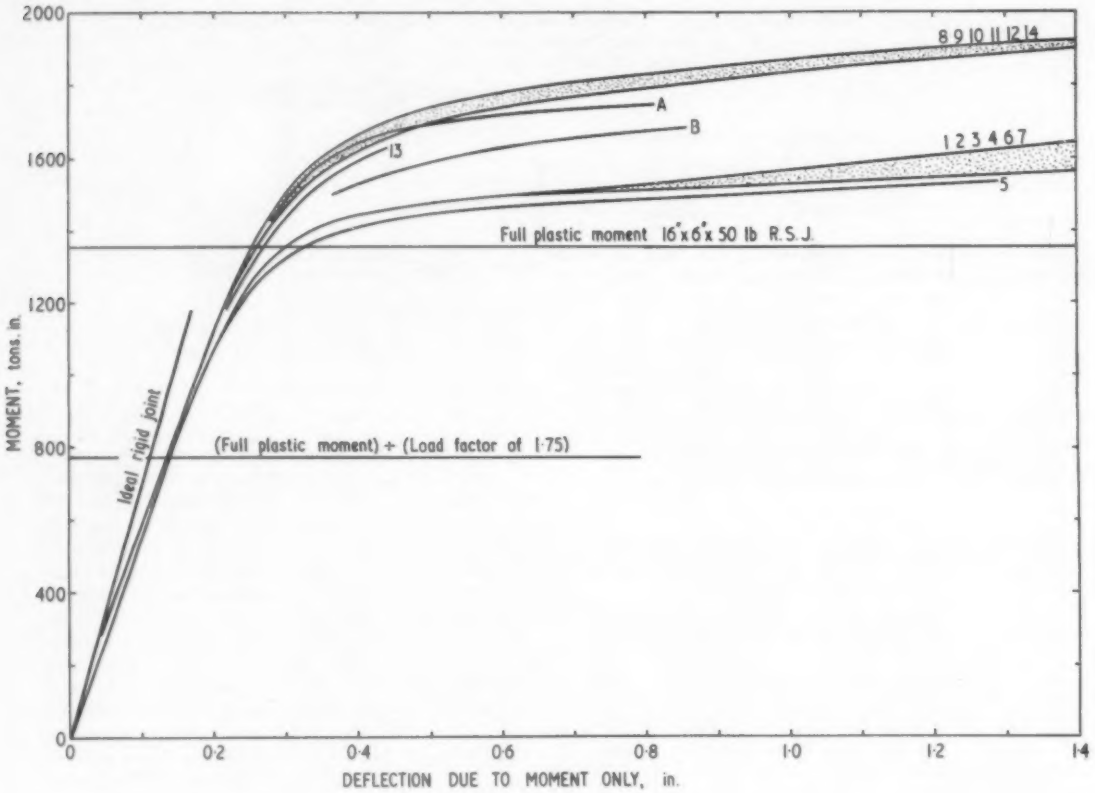
When tested, all seven specimens proved themselves more than adequate to the task of transmitting the theoretical full plastic moment of the 16×6 in.×50 lb joist. In fact the smallest moment required to produce a weld failure was 1650 in. tons, which exceeds the full plastic value by 22%. This particular weld fracture, which occurred in specimen 13, was accompanied by a deflection of only 0·5 in. and was due to the fact that part of one of the tension flange welds was rather under size. Weld failures also took place in specimens 9 and 11 but at the considerably higher moment of about 1860 in. tons. At this higher moment there was appreciable secondary bending about the minor axis of the beams owing to the absence of lateral restraint, and it is certain that this factor was largely responsible for the weld fractures. For instance, it was noticed that one weld failure started near the toe of the tension flange of the beam on the side where the two principal tensile stresses were additive.

Considering tests 8–14 as a whole it is very noticeable that all seven moment/deflection curves stay close together throughout the whole range. This is partly because all the beams were from the same rolling, but the really interesting feature is that the variations in stiffener sizes and degree of fit do not seem to have had any significant effect on the overall rigidity of the joint. This is perhaps a little surprising but nevertheless it is a comforting conclusion, for it means that a certain degree of latitude can be allowed in the design of stiffeners and more especially in the workmanship also.

Summary of Experimental Results

The first cracks in the shiny surface of the resin invariably took place in the extreme fibres of the tension flange near the face of the stanchion. These cracks began to spread and were quickly followed by similar cracks in the compression flange near the angle cleat. Further loading caused the yielded zones to spread inwards towards each other until almost the whole of the resin had flaked off the web of the beam, except quite close to the stanchion where the section was stiffened by the angle cleats. All this quite natural behaviour was entirely as predicted and calls for no further comment.

It was most noticeable that the stanchion and stiffeners showed hardly any signs of yield at any stage during the test. As the loads were balanced, the stanchion web did not have to take an out-of-balance



6—Moment/deflection diagrams for all specimens

shear force, so it is not really surprising that that part of the joint showed little sign of distress. The stiffeners were designed to take the forces in the flanges of the beams but it was obvious that these loads had been spread by the fillet welds and stool cleats into adjacent parts of the stanchion. This feature is most desirable because a stanchion may be subjected to high axial stresses in addition to such transverse loading. This distribution of stress was one of the reasons for the selection of fillet welds rather than butt welds.

As in the previous series of tests* it was again very significant that the angle of weld failure did not even approximate to the generally accepted figure of 45°. The tension flange of the beam was pulled away from the face of the stanchion taking with it only a very small quantity of weld metal, giving a plane of failure almost at right angles of the axis of the stanchion. This plane of failure obviously has a bigger area than the 45° throat and provides further evidence to support the argument in favour to the adoption of unequal sided fillet welds for this type of stress distribution.

Looking at the experimental results, it is obvious that every joint was more than capable of transmitting the theoretical full plastic moment of a 16×6 in.×50 lb RSJ. The only weld fracture which can be described as somewhat premature is that of specimen 13, but this is easily accounted for by a slightly undersize weld. Specimens *A* and *B* failed before the deflection had become large but this was remedied in subsequent tests by the local increase in the size of the web-to-stanchion welds adjacent to the root fillets on the tension side of the beam. Even specimens 3 and 4, which had $\frac{1}{8}$ in. end clearance, did not suffer weld fracture and behaved quite as well as, if not better than, some joints with $\frac{1}{16}$ in. or even no end clearance.

As far as rigidity is concerned the moment/deflection characteristics shown in Fig. 6 are so close together in the working range that it is virtually impossible to distinguish between them. This is quite remarkable when one considers the variations in weld sizes, stiffener thicknesses, and end clearances which were incorporated in this range of sixteen test specimens. Not only were there slight differences in the basic design but the fabrication and welding was carried out in different workshops using steel from different rolling mills. In spite of all these variables, the test results were very consistent and everything points to the conclusion that the fundamental design is satisfactory and that slight discrepancies in workmanship and assembly are not likely to prove dangerous.

From the moment/deflection curves of Fig. 6 it is apparent that the beams used in tests *A*, *B* and 8–14 had a higher yield stress than that of the beams used in tests 1–7. These two main groups are shown as separate collections of curves which form narrow bands

*See earlier footnote (p. 368).

at deflections greater than 0·3 in. but almost coincide in the elastic range.

Conclusions and Recommendations for Design

All these specimens were to the same basic design and had invariable beam and stanchion sections. The loading was symmetrical and equal in all cases. Therefore the following conclusions are strictly true only for beam-to-stanchion connections which are similar in all respects to those tested. Further work will have to be undertaken to cover non-symmetrical loading conditions and perhaps also other combinations of beam and stanchion sizes. In spite of these restrictions it is considered that the following recommendations will be of some value to practising structural engineers.

(1) If a beam-to-stanchion connection is designed according to the details shown in Fig. 5, and the throat areas of the fillet welds are made equal to or greater than the corresponding sectional areas of the joist, the connection will safely transmit the theoretical full plastic moment of the beam. But there must be a local increase in the size of the weld joining the web to the face of the stanchion adjacent to the root fillet on the tension side of the beam.

(2) Variations in end clearance of up to $\frac{1}{8}$ in. do not seem to have any effect on the sizes of fillet weld required. Since only two tests were carried out on connections having $\frac{1}{8}$ in. gap it is probably desirable to add $\frac{1}{16}$ in. to the size of all fillet welds if the end clearance exceeds $\frac{1}{16}$ in.

(3) Each web stiffener should be half the width of the flange of the beam and approximately the same mean thickness.

(4) The web stiffeners should be carefully made but they do not have to fit exactly to the stanchion profile. The stiffeners should be in contact with the web of the stanchion but a local clearance of not more than $\frac{1}{32}$ in. between flange and stiffener is quite acceptable.

(5) Stiffeners in compression may be positioned by continuous $\frac{3}{16}$ in. fillet welds.

(6) Stiffeners in tension must have flange welds equal to those which connect the beam to the stanchion. The web welds require to be only $\frac{3}{16}$ in. fillets.

Acknowledgments

The work described in this report was carried out at the Engineering Laboratory, Cambridge University, under the direction of Professor J. F. Baker, Head of the Department of Engineering. It forms part of a general investigation into the behaviour of steel structures in the plastic range being carried out at Cambridge with the support of the British Welding Research Association.

The willing co-operation of Mr. M. F. Palmer and Mr. H. A. Cadwell, together with their respective companies Joseph Westwood and Co. Ltd., and Edward Wood and Co. Ltd., is gratefully acknowledged. They were not only responsible for undertaking the fabrication of specimens 1 to 14, but also made a number of valuable suggestions.

B.W.R.A. REPORT OF COUNCIL FOR 1958–59

The Fourteenth Annual Report of the British Welding Research Association, covering the period 1958–59, has been distributed to members. A brief summary of some of the more interesting items is given in the following pages, together with extracts from reports of the activities of the research committees. 488

THE Fourteenth Annual Report of the Council outlines some of the difficulties facing the Association, which serves more than 20 different industries. Each of these industries has specific welding problems which need investigation, and it is inevitable that the Association should maintain its research activities on a broad basis to serve all its members.

At the same time, members of the staff produce papers and give lectures, particularly in connection with the School of Welding Technology of the Institute of Welding; they also serve on technical committees of Government departments, the Institute of Welding, other professional institutions, and the British Standards Institution.

While the Council welcomes this pressure on the staff as evidence of confidence by industry in the Association's work, it expresses concern that the orderly and uninterrupted progress of research work can no longer be assured, unless sufficient funds for the necessary expansion are available.

The programme for the coming five years lists over 50 major projects, including current researches, which will cost an estimated £1,000,000. This means that the Association will need an annual income of £225,000 – £250,000. It is hoped to obtain this by £105,000 from industrial subscriptions from members, by £69,000 from the D.S.I.R., and by £50,000 – £75,000 from non-grant earning sources.

To qualify for the increased grant aid from D.S.I.R. the Association must be assured of the industrial income of £105,000, so the Council is appealing to all members and prospective subscribers to make the programme possible.

New Council

The Council is particularly gratified that Sir Charles Lillicrap, K.C.B., has agreed to serve for another year as President; and that Sir Donald Bailey, O.B.E., has been persuaded to serve as a co-opted member of Council.

A list of current officers and members of Council is published each month in the front section of the *British Welding Journal*.

Membership

The continued interest in the Associations' work and the services it offers is reflected in the increase of membership; during the year thirty-five new members have been elected.

Co-operation with Other Organizations

The friendly and mutually advantageous co-operation with the Institute of Welding, in publishing and educational activities, and the collaboration with several metallurgical and engineering associations is now firmly established. Organizations which deserve special mention are: the Aluminium Development Association; the British Constructional Steelwork Association; the British Iron and Steel Federation; the Copper Development Association; the Gas Plant Manufacturers Development Council; Pametrada; the Shipbuilding Conference; the Tank and Industrial Plant Association; and the Water-Tube Boilermakers' Association.

The Council also acknowledges with gratitude the friendly collaboration from other research organizations and universities, particularly the British Iron and Steel Research Association, the British Non-Ferrous Metals Research Association, the British Shipbuilding Research Association, the Universities of Birmingham, Bristol, Cambridge and Durham, the Imperial College of Science and Technology, Manchester College of Technology, University College Swansea, and University College Cardiff.

There is a special indebtedness to the Department of Scientific and Industrial Research, whose staff spare no effort in helping and giving constructive advice.

Friendly co-operation continues with the Admiralty, and there is exceptionally useful collaboration with the Ministry of Supply on general matters of common interest and on sponsored researches. The Council also acknowledges the helpful support from the Atomic Energy Authority on welding problems associated with reactor construction.

The availability of an organization with specialist scientific staff and experimental facilities, capable of tackling when needed urgent and often very intricate welding problems, is a national asset, and the Council is sure that this fact is fully appreciated by Government departments, the public corporations, and the associations representing manufacturing interests.

It also feels confident that the growing appreciation of the importance of this function, coupled with the valuable contribution the Association is making towards the solution of welding problems, will encourage these bodies, and members generally, to provide the Association with the additional money, which with the increased total D.S.I.R. grant of £69,000, will enable it to attack the long list of outstanding problems which remain unsolved only because there are no funds for their investigation.

Priorities Assessment Survey

A statement has been circulated to members, outlining more than 50 major problems, and asking members to indicate those in which they are interested and to measure their relative importance by means of a points system.

The result of this survey will provide useful information for the Council and the Research Board in allocating the available funds, which are not sufficient to meet wholly the number of problems requiring investigation in the immediate future.

Finance

The income for the year was £156,995 and the expenditure amounted to £170,335, with a capital expenditure of £22,186 on buildings and equipment. Future capital expenditure to enable the Association to prosecute the present research programme successfully is estimated at £145,000, and it will be obvious from this, and the limited reserves of the Association, that a substantial increase in income will be necessary over the next few years.

Publications

During the year 49 research reports, booklets, and translations of reports on research carried out abroad, mainly in Russia, were sent to members. The regular translation of the Russian periodical 'Automatic Welding', for which special financial aid has been obtained from the D.S.I.R., is being distributed to members and other interested persons in the Commonwealth, the U.S.A., and Western Europe for an annual subscription of £10 10*s* 0d, and plans have been made for similar regular translation of another Russian journal 'Welding Production'.

Consultative and Advisory Service

The range and number of problems submitted during the year have been greater than ever before, and there has been a steady increase in the number of visitors to the laboratories and to the advisory section in London for the discussion of welding problems. There have been many enquiries relating to the design of welded structures, often resulting from fatigue failures. It is an encouraging sign that more prototype designs are being submitted for criticism.

There is an increasing awareness of the need for early consultation with experts in design problems. and it is the intention of the Association to meet this need as soon as the necessary funds become available. It is hoped to start a new design service that will, among other activities, be able to translate the results of research into practical industrial applications.

Research

The structure of the reorganized research committees is shown in the accompanying table. During the year four committees that had completed their projects were disbanded. They were: A2 – Non-destructive methods for the examination of welds; B3 – Projection welding of steel; D1 – Load-carrying capacity of frame structures; and D3 – Advisory Panel on pressure vessels for the IIW Commission XI.

Some details of the progress in research is given in the following four sections: researches completed, researches in progress, those being planned, and work supported at Universities.

Completed Researches

(1) Investigations into gas shielded welding have produced much new information on the influence of power source, welding speed, and current in the CO_2 welding of sheet materials and steel. The use of nitrogen/argon mixtures has been found to be beneficial in the welding of copper.

(2) It has been concluded from investigations into hot-cracking of mild and low-alloy steel weld metal that no simple test can cover all the variations possible, and instead limits for the weld metal composition have been specified. On the other hand, liability to cold cracking or fissuring, which is related to the rate of cooling of the weld, the longitudinal weld restraint, and the presence of hydrogen, can be determined from microscopic examination of beads laid on the appropriate plate.

(3) Continued studies on brittle fracture problems using in particular the 'wide plate test' have shown that the stress at which fracture occurs is dependent on the type of electrode used. With rutile electrodes the fracture stress is surprisingly low but any cracks are limited in extent. Low-hydrogen welds resist fracture up to high levels of stress, but because of the larger amount of energy available for propagation, cracks once started are more liable to continue.

Examination of steels has shown that microstructures have a significant influence on the transition temperature.

(4) The welding of high-strength aluminium alloys has, in the past, been considered to be an impossibility, because

RESEARCH BOARD

Advisory Committee

GROUP A		**FUNDAMENTAL RESEARCH**
	A1	Arc welding process characteristics
	A3	The fundamentals of resistance welding and test methods
	A4	Oxygen cutting
GROUP B		**FERROUS METALS**
	B1	The welding of mild steel
	B2	The welding of low alloy steels
	B4	The spot and seam welding of heat-resisting alloys and steels
	B5	The welding of chromium/nickel and austenitic steels
	B6	The influence of residual stresses in welded structures
	B7	Investigating the brittle fracture of 3-in. thick steel plate
GROUP C		**NON-FERROUS METALS**
	C1	Welded medium strength aluminium alloys
	C2	The welding of high-strength heat-treatable aluminium alloys
	C3	The arc welding of copper
	C4	Welding of titanium and its alloys
	C5	Welding of aluminium bronzes
GROUP D		**ENGINEERING APPLICATIONS**
	D2	The effect of defects on the fatigue strength of butt welds in mild steel plate
	D3	Stresses in welded pressure vessels
	D4	Strength of openings in welded storage tanks
	D6	Reclamation of shafts by welding
	D7	Fatigue testing of welded structural details
	D8	The influence of locally induced residual stresses on the strength of welded structures

of the low strength and brittleness of the welds. A suitable filler alloy has now been developed (Cusil 73) for joining the H.14 and H.15 alloys in certain applications.

(5) The effects of atmospheric contamination in titanium welds have been studied and permissible levels have been determined. It has also been shown that surface contamination seriously reduces bend ductility.

(6) Considerable progress has been made on investigations of the fatigue properties of welded components. Comparative tests under alternating bending of as-welded and stress-relieved pipe butt welds showed that heat-treatment provided no improvement in fatigue properties.

Box sections, fabricated by various methods of welding, and of particular interest to the motor industry, have been tested in torsional fatigue. Spot welding has been found to be quite satisfactory, but the low strength of intermittently welded fillet joints indicates that continuous automatic welding of these thin gauge members would be preferable.

Work that has continued on the fatigue strength of transverse butt welds in mild steel shows that the reinforcement shape has a considerable influence on strength. It appears that the method of edge preparation and stress-relief treatment have little influence on the fatigue strength of the specimens tested.

(7) The Association has continued to expend considerable effort on work aimed at improvement of design methods for welded pressure vessels. Further tests on branch connections show that reinforcement is not necessary for thick vessels working at current levels of stress. It has also been found that a short tubular rim is sufficient to reinforce the manhole openings to oil storage tanks. Fatigue tests on nozzle details have clearly shown that present-day working pressures under these conditions could be increased, or reinforcement dispensed with.

Researches in Progress

(1) The effects of wire diameter, arc voltage, and shielding gas on metal transfer in the welding of steel have been studied. This work will enable the loss of additions to the filler wire across the arc to be determined with greater accuracy.

Similar experiments on the aluminium arc have resulted in the development of a torch for fine-wire welding, and in a greater knowledge of the arc characteristics.

(2) The post-heating of spot welds in quench hardening steels greatly increases their ductility, but the selection of the most suitable machine settings has not been easy. The development of a suitable test specimen and micrographic investigations have provided useful information from which the most suitable treatment can be predicted.

Preliminary work on the spot and seam welding of heat-resisting materials has given useful information on the optimum welding conditions and room-temperature properties of welds in the chrome-bearing alloys and steels. Further work is to be done at elevated temperatures.

(3) It is hoped that fundamental investigations of the properties of mild steel weld metals will lead to a better understanding of certain anomolous phenomena. The first tests are being made on the same materials but using different welding processes. Electron-micrograph studies have already shown a possible reason for the better yield properties of the weld as against similar wrought material. Although heat-affected zone cracking can be controlled in the welding of low-alloy steels, mainly by the use of low-hydrogen type electrodes, there is much yet to be learned of the effects of various alloying elements on weldability. The Association's current work on this problem consists of an examination of a series of 16 steels specially selected to show the effect of alloying elements. At the same time a technique has been developed for introducing hydrogen into test specimens for dead-load rupture tests. A significant finding has been that specimens can be saturated with hydrogen at 900°C. after a time of only 15 min. Cracking and fissuring in stainless steels is also being investigated by tension tests on fused spots as they are cooling from the molten state. These enable the temperature of cracking to be determined. High-temperature ductility is also being measured by means of torsion tests.

(4) An important feature of a material in its resistance to brittle fracture is its 'fracture toughness'. Experiments are being carried out to devise a test for measuring this factor on a small plate sample. Fracture initiation phenomena are also being studied.

The 2000-ton thick plate test rig has been proved beyond its rated capacity and is now being used for tests on 3-in. thick plate.

(5) A survey of current practice in the selection of filler alloys for welding low and medium strength aluminium alloys is being made so that the need for further work can be assessed.

Data on the significance of weld defects are also being collected so as to relate radiographic appearance to mechanical properties for control purposes. The relationship with fatigue performance may also be investigated.

(6) Thin gauge zinc-deoxidized copper has been successfully welded by the argonarc process, and experiments are being undertaken on the welding of phosphorus-deoxidized copper by the self-adjusting arc process using filler wire containing deoxidants.

(7) The self-adjusting arc process is also being used to study the welding behaviour of single-phase aluminium bronzes using duplex and single-phase filler wires. Corrosion tests are being carried out on the welds.

(8) The welding of zirconium, a metal of particular interest to the nuclear engineering industry, is being studied in relation to the corrosion resistance of argonarc and self-adjusting arc welds. A precision welding head has been constructed for self-adjusting arc welding, and the effect of arc voltage on porosity is being studied.

(9) Although certain programmes of work on fatigue have been completed other essential investigations are in hand. Properties of various joints in medium-strength aluminium alloys are being determined for welds made by different processes. As with steel, the welding process seems to have less effect on fatigue properties than the surface condition of the weld. The high-strength materials are also to be investigated. Cladding appears to reduce strengths to about half that of the unclad material.

The effects of various forms of defect and their degree on the fatigue strength of butt welds in mild steel plate are being systematically investigated so that non-destructive examination can be used with a greater knowledge of what defects are harmful.

Repairs by welding are always subject to uncertainty in regard to their fatigue behaviour, and worn shafts built-up by welding often fail relatively soon after repair The Association is co-operating with the IIW in a general investigation of this problem.

The absence of reliable guidance on the dynamic behaviour of welded structures and structural connections has prevented a more economical use of this form of construction. The Association is attempting a limited programme of work on the fatigue behaviour of stiffeners welded to the tension flanges of girders and a comparison of the fatigue properties of welded mild steel and high-tensile steels. Useful information has already been obtained from preliminary experiments on spot heating to increase the fatigue strength of discontinuous longitudinal welds. There is direct evidence that induced stresses from spot heating or local compression can double the strengths of welds in both mild steel and aluminium alloys.

An extensive programme of research is being conducted to determine the fatigue properties of thin-gauge welded heat-resisting alloys.

(10) A digital computer is being used to calculate

stresses around branch connections in spherical shells with the object of providing design data.

The resistance of connections between tubes and tube plates to fatigue failure is being investigated to establish more rational methods of design and to discover the most suitable disposition of the tubes.

A special machine has been developed for applying pressure pulsations to welded joints in high-pressure piping. The tests will enable a comparison to be made between the efficiencies of various forms of joint and will indicate the permissible stress levels in an industrial installation.

Future Researches

(1) Though much fundamental work has been done on the physics of the arc, it needs to be correlated to provide guidance on fundamental principles. The metal transfer characteristics of wire in the inert-gas metal arc process will be determined for various materials and in as many gases as possible.

(2) Low-alloy steels are being used to an increasing extent to replace the traditional mild steel for boilers and pressure vessels, and it is necessary to determine the susceptibility of these materials to fatigue cracking at branch connections. A simple test specimen is needed so as to compare behaviours with mild steel, for which full-scale pulsating tests have already been carried out.

The stresses in branch connections in thin vessels under internal pressure are to be determined. When this is done the stress concentration factors for branch connections fitted to drums of three different ratios of thickness to diameter will be known.

Gusseted pipe bends are a common form of construction and their resistance to failure under repeated loadings is to be measured.

Work on the fatigue strength of welded aluminium alloys is to be extended to studies of the properties of the weld metal and heat-affected zones of the parent plate and of the influence of internal defects on fatigue strength.

Researches at Universities

Cambridge – *Department of Engineering*

(1) The pioneering work on the plastic behaviour of continuous structures is continuing, and tests have been made to ascertain the ultimate behaviour of bolted and welded connections. Suitable weld sizes have been determined for joining beams to columns, and the ability of preloaded high-tensile bolts to develop a sufficient moment of resistance to create plasticity in the beam has been demonstrated.

(2) Tests on stanchions stiffened locally at beam intersections have shown that the empirical design method for stiffeners in BS. 449 is adequate.

(3) Local buckling of members in compression can reduce the full plastic moment available in the member in a continuous structure. A programme of tests has been initiated to determine the conditions under which such buckling can occur, especially with broad flange sections.

(4) Full-scale tests on individual structures continues. One series on slender portal frames proved that strain hardening of the material during plastic deformation entirely masked the effect of the deformation itself on the predicted collapse load.

Cambridge – *Department of Metallurgy*

The influence of structure on absorption and distribution of hydrogen in a number of metals is being studied so as to provide more knowledge of the effect of hydrogen on the properties of welded joints.

Swansea University College

Rigidly jointed truss frames are continuous structures and should be amenable to treatment by the plastic design theory as soon as collapse characteristics are determined. A first series of tests has been made to establish the load-deformation characteristics of truss members in the plastic range, particularly those in compression. Some theoretical predictions for singly redundant trusses have been made, and these are to be verified from tests on frames with mild steel and light alloy struts.

Filler Materials

Book Review

ORVILLE T. BARNETT, "*Filler Metals for Joining*": New York, 1959, Reinhold Publishing Co.; London, Chapman and Hall Ltd. ($7, 52*s*.6*d*.)

This book has been written for use in America but it can be recommended as a reference book for British readers. It contains much useful and interesting information but it could have been improved by better editing.

The book is free from serious technical errors and misprints although the illustration on page 15 is inverted. The index appears to be adequate and compensates for some deficiencies in the arrangement of the text.

Many of the illustrations contribute nothing of value to the book, and some paragraph headings appear to have been inserted with insufficient regard for the subject matter.

Opinion may be divided regarding the staccato style of writing in parts of the book but there can be no excuse for the frequent misuse of words. The meaning of some sentences may be inferred from their context but by themselves they are nonsense: *e.g.*, on page 9—"Boiling water of course is not used for production, but it is a convenient way to obtain uniformity of results among different testing groups".

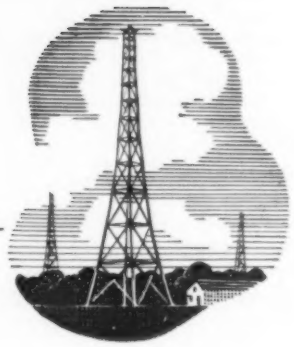
The extensive use of the A.W.S. electrode classification codes as paragraph headings has the disadvantage that a reader unfamiliar with this code must continually refer to the tables, most of which are printed so that the book must be turned sideways to read them. It would be better if they were printed to avoid the need to do this, or alternatively if the paragraph headings were extended to include the composition of the filler wire to which they refer.

The footnote on page 18 should be made part of the introduction.

In spite of these faults this book fulfils its purpose admirably and it is to be hoped that in its next edition the opportunity will be taken to eliminate its present faults.

I. C. FITCH

NEWS
and Announcements



News of the Institute and Branches
B.W.R.A. · Other Societies ·
and Industry

INSTITUTE ACTIVITIES

Honorary Officers and Council 1959–60

At the Annual General Meeting of the Institute, held at 54 Princes Gate on 16th July, 1959, the following Honorary Officers were elected unopposed:

President
E. Seymour-Semper, M.I.Mech.E., F.R.S.A., M.S.E.

Vice-Presidents
W. Barr, O.B.E., A.R.T.C., F.I.M.
E. Fuchs, M.A., A.M.I.Mech.E.

Hon. Treasurer W. E. Harriss

The following were elected to represent the classes named in the ballot:

Ind. Corp. Members
E. F. Burford, M.B.E.
N. L. G. Lingwood

Fellows, Members, and Associate Members
D. J. W. Boag; D. C. C. Dixon; E. P. S. Gardner; D. B. Kimber

Companions
J. Hooper

Associates
A. Evitts

Mr. Seymour-Semper is a Director of Hancock & Co. (Engineers) Ltd. A biographical note appeared in the December 1958 issue of the *Journal* (p.578).

Mr. Barr is the Chief Metallurgist of Colvilles Ltd., and was recently elected President of the Iron and Steel Institute.

Mr. Fuchs is Welding Engineer in the Alkali Division of Imperial Chemical Industries Ltd.

Sir William J. Larke

A memorial service to Sir William J. Larke, K.B.E., was held at St. Margaret's, Westminster, on 16th June last. Canon Michael Stancliffe officiated, and an address was given by the Archdeacon of Bromley, the Ven. R. G. H. McCahearty. The Bishop of Tonbridge, the Right Rev. Russell B. White, read the lesson.

The Institute of Welding was represented by the Secretary, Mr. G. Parsloe, and the British Welding Research Association by Mr. A. Robert Jenkins, J.P., Chairman of the Council, Dr. R. Weck, Director of Research, and Mr. A. O'Neill, Secretary.

Library

Miss Patricia Gray has been appointed an additional assistant in the Library.

School of Welding Technology

The following is a list of Courses to be offered at the School from September 1959 to March 1960. All Courses to the end of October are fully booked and have waiting lists; very early application is recommended for the later Courses.

1959

22nd–30th Sept. D.17—Advanced Course for Welding Engineers

12th–16th Oct. D.1/2—Welded Design and Construction of Pressure Vessels and Pipework

26th–28th Oct. D.12/1—Control of Distortion

29th–30th Oct. D.13/1—Residual Stresses and Stress Relief

9th–13th Nov. D.2/1—Welded Design and Construction in Aluminium Alloys

23rd–27th Nov. D.10/1—Welding in Shipbuilding

7th–11th Dec. D.5/2—Inspection and Testing

1960

4th–15th Jan. D.27—Practical Ultrasonics for Operators

25th–29th Jan. D.4/1—Resistance Welding

8th–12th Feb. D.22—Welding of Atomic Energy Plant

22nd–25th Feb. D.28—Welding for Junior Management

7th–11th March. D.11/1—Inert-Gas Arc Welding

21st–25th March. D.6/2—Welded Design and Construction in Corrosion- and Heat-Resisting Materials

ELECTION OF MEMBERS

The following elections were made at the Council meeting of 12th March 1959:

Members

J. L. Roberts (Newcastle on Tyne); **G. R. Rotchild** (New Jersey, USA); ***S. Hong Sung** (Hong Kong); **L. Van Ouwerkerk** (Rotterdam, Holland); **R. J. Barber** (Widnes); †**E. P. Boddaert** (Montreal, Canada); **J. C. Borland** (Stapleford); **J. A. Briggs** (Wakefield); **F. C. Brown** (Leeds); **A. Bunting** (Gillingham); †**G. H. Capell** (Broadwell-on-Sea); ‡**G. F. Charge** (Enfield); †**G. Coates** (Knutsford); **D. W. Dighton** (Rochester); †**H. S. Drew** (Tipton); †**A. L. Fishwick** (London); **F. Fountoulis** (Athens, Greece); †**R. J. Gardener** (Hockley); **E. N. Gregory** (Enfield); §**A. J. H. Griffiths** (Wolverhampton); **F. P. Hahn** (Middlesbrough); **A. E. Hardy** (Leeds); **R. E. Hind** (Bishopthorpe); **R. I. Hixon** (Swansea); **G. Holmes** (Warsley); **R. D. Johnston** (London); **R. A. Kirkin** (Lee-on-Solent); **R. Knott** (Middlesbrough); **R. Lawson** (Newcastle on Tyne); †**P. E. Leach** (Salford); †**R. V. Leicester** (Peterborough); †**J. W. Mackinnon** (Paisley); **V. Manickam** (Bangalore, India); ‡**J. J. Maye** (London); **D. G. McCallum** (Esher); **D. Murdoch** (Cheadle Hulme); †**L. N. Sayer** (Birmingham); **B. Yuen-Juang Shen** (Hong Kong); **J. F. Simpson** (Leeds); **A. Standeven** (Manchester); †**D. B. Tait** (Wolverhampton); **L. Taylor** (Newcastle on Tyne); **R. J. Towler** (Banstead); †**D. Whitehead** (Rainford); **R. Williams** (Dronfield); †**R. L. Wright** (Eastleigh).

Companions

A. N. Anderson (Kingston, Jamaica); ‡**M. Clarke** (Chelmsford); **T. Hughes** (Workington); **E. Ingham** (Leeds); **K. R. Jefferson** (Gateshead); **S. Lumley** (London); **J. Macintyre** (Kilbarchen); **A. T. Marriot** (Dore); **E. V. Oliver** (Woking); **N. Smith** (Canterbury); **R. F. Stevens** (Kirkuk, Iraq); **D. D.**

Taylor (Downfield, Dundee); **J. Tod** (Wrexham); ‡**A. V. Valentine** (Cardington); ‡**K. W. Wagstaff** (Eastbourne).

Graduates

J. M. Allcock (Toddington); **T. B. Singh** (Calcutta, India); **H. A. Davies** (Newport); **F. D. Duffin** (Belfast); **J. Frey** (Manchester); **C. E. P. Harrison** (Bristol); **D. S. Honavar** (Bombay, India); **A. Hurst** (Sheffield); **W. J. L. Oliphant** (Peterborough).

Associates

R. Banks (Horwich); **A. C. Blower** (Shildon, Co. Durham); **G. P. Browning** (Bebington); **J. E. Carter** (Horwich); **J. Connor** (Widnes); **S. Copley** (Doncaster); **D. Cunliffe** (Jericho, Bury); **K. D. Farrant** (Llanharry); **E. F. Ferris** (Plymouth); **L. France** (Atherton); **W. H. Gallaghan** (Hull); **J. H. A. Godwin** (Abbot's Langley); **N. T. Gutteridge** (London); **J. Hill** (Manchester); **H. Homfray** (Marlow); **R. Horne** (Calcutta, India); **J. F. Hunter** (Glasgow); **N. B. Livsey** (Barnoldswick); **B. McLean** (Glasgow); **N. J. Mullen** (Dublin); **T. J. Murphy** (Southampton); **J. H. O'Connor** (Glamorgan); **C. H. Oldham** (Swansea); **A. J. Packer** (Southampton); **W. J. Penny** (Eastleigh); **W. G. Rhodes** (Dartford); **C. J. Summerhill** (W. Bromwich); **G. C. Tuffley** (Lincoln); **A. R. Walker** (Corby); **R. E. Warner** (Stockingford); **C. E. R. Watler** (London); **G. Watson** (Cowpen, Blythe); **T. G. Woods** (Coatbridge).

The following elections were made at the Council meeting of 4th June 1959:

Members

T. Storey (Stockport); **D. Stuart** (Sale); **P. D. Blake** (Bishops Stortford); **R. J. Foster** (Betchworth); **M. F. Jordan** (New Barnet); *B. K. Mitter** (Bhopal, India); **L. Nekanda-Trepka** (Warsaw, Poland); **H. J. Nichols** (Monwerille, USA); *W. E. **Springer** (Ontario, Canada).

Associate Members

I. Abernethy (London); †**D. G. Claydon** (Drayton); **G. V. Davies** (Shirley); **S. C. Dey** (Assam, India); **J. J. Doyle** (Glasgow); **G. G. Edmonds** (Birmingham); §**R. H. Edwards** (Porthcawl); ‡**J. Foster** (Glasgow); §**J. W. Gethin** (Wolverhampton); **M. M. Ghosh** (London) ;**J. M. Gibson** (Newcastle on Tyne); **F. D. Goodman** (Woking); ‡**H. A. Harrison** (Middlesbrough); **G. E. James** (Cardiff); **J. W. Jeffrey** (Blackpool); **R. Liversedge** (Flixton); **H. J. Manners** (Bristol); **J. Marshall** (Dudley); **P. A. Masters** (Portbury); **F. Monaghan** (Leigh); **J. W. Morgan** (Bristol); **J. Morton** (Sunderland); **A. W. Parsons** (Upton) **F. W. Pillinger** (Norton); **J. T. Robertson** (Sevenoaks); **C. D. Ryder** (Liverpool); ‡**W. Schofield** (Horwich); **D. H. Scott** (Berkhamsted); **A. W. Thorne** (Wolverhampton); **P. H. Titman** (Leeds); **A. R. Woodward** (Banbury); ‡**A. W. Marshall** (Edinburgh).

Companions

G. C. McAsey (Liverpool); ‡**W. Mullen** (Eastleigh); **D. G. Raymond** (Stanford-le-Hope); **N. H. Townend** (Codsall); **N. Tristram** (Rochester).

Graduates

B. Cartwright (Sheffield); **R. C. Chopra** (Calcutta, India); **M. J. Siverns** (Bilston); **D. B. Wimpenny** (Runcorn).

Associates

N. D. Ashton (Bolton); **G. E. Barnes** (Edmonton); **E. J. Chillingworth** (Enfield); **J. L. Clelland** (Coatbridge); **W. G. Cooke** (Stoke-on-Trent); **S. K. Das** (Calcutta, India); **C. H. Goodman** (Birmingham); **G. T. Hill** (Rhuddlan); **D. Jewsbury** (Enugu, E. Nigeria); **M. Penson** (Wolverhampton); **C. J. Piper** (Potters Bar); **J. Roy** (Blaydon-on-Tyne); **H. A. Russell** (Brentwood); **L. A. Sullivan** (Barking); **G. E. Whalley** (Church, Accrington); **P. F. Woods** (Birmingham).

Industrial Corporate Members – Class 1

Civil Engineer-in-Chief's Department, Admiralty (Pinner); **Director General of Weapons, Admiralty** (Bath); **Ship Department, Admiralty** (Bath); **Metallisation Limited** (Dudley); **Metal and Plastic Coatings Association** (London).

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* Transfer from Associate-Member

† Transfer from Graduate ‡ Transfer from Associate

§ Transfer from Companion

MEETINGS

Electroslag Welding

A half-day meeting to discuss various aspects of electroslag welding will be held at the offices of the Institute on the afternoon of Thursday, 1st October 1959.

The following have offered to contribute papers, which will be published in the *Journal*:

D. W. J. Boag and W. K. B. Marshall of Rockweld Ltd.

J. A. Lucey of Quasi-Arc Ltd.

A member of Fried. Krupp Maschinenfabriken, Essen

Annual Dinner

The Annual Dinner of the Institute will be held at the Park Lane Hotel on Wednesday, 4th November 1959.

The guests of the Institute will include some 40 members of the French Society of Welding Engineers who are joining in the Autumn Meeting. This is being held from 3rd to 6th November, with the subject of Quality Control in Welding.

NEWS OF MEMBERS

C. C. Bates, Technical Director of Welding Supervision Ltd., has been appointed a Director of the associate company Cathodic Corrosion Control Ltd.

Walter Swire, Consulting Engineer, has changed his office address to 30a Carlton Street, Leeds 2. (Tel.: Leeds 30321 and 671649.)

R. Noble has recently taken up the post of General Manager with the Northern Welding Co. Ltd., Northampton. Before moving from Sheffield to take up this appointment he was an active member of the Sheffield and District Branch Committee.

A. E. Attwell, was recently appointed Works Superintendent with the Quesnell Manufacturing Co. Ltd., British Columbia.

C. H. Bentley, a companion now attached to the South London Branch, recently left the employment of Cooper & Turner Ltd., of Glasgow, to take up an appointment with The English Electric Company, and will be responsible for the Company's welding activities in London and the South East.

R. G. C. Stephenson has been transferred to Australia as Managing Director of The Commonwealth Industrial Gases Ltd., in Alexandria, New South Wales.

A. A. Smith, a Principal Scientific Officer of the British Welding Research Association, has been seconded to the DSIR by the Association. He recently left for the USA to take up a temporary appointment with the United Kingdom Scientific Mission, 1907 K Street, N.W., Washington 6, D.C. Mr. Smith will be studying mechanized welding techniques in the USA, with special attention to gas-shielded metal-arc welding.

R. Williams (Assoc. Mem., Manchester Branch) has recently taken up an appointment as assistant manufacturing Welding Engineer with Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester.

E. M. Wilson (Assoc. Mem., South Western Branch) has now left Aluminium Laboratories Ltd., Banbury, and holds the post of Assistant Welding Engineer with Bristol Aerojet Ltd., Banwell, Somerset.

Obituary

The Council regrets to record the deaths of the following members:

A. A. J. Mitchell (Tyneside Branch, Associate 1945).

T. R. Edwards (Wolverhampton Branch, Associate 1950).

J. A. Matthews, Chief Engineer of the Eagle Star Insurance Co. Ltd., Engineering Dept. (South London Branch, Member 1943).

Frank Brown on 26th March (Member 1945, West of Scotland Branch).

CONTRIBUTOR TO THE JOURNAL

Sidney Wise, A.M.I.Mech.E., is a Senior Scientific Officer in British Railways Research Department at Derby.

He was educated at the Sloane School, Chelsea, and at Crewe Technical College, and later at the Manchester College of Technology. After he had received training as an Engineering Apprentice at the Crewe Locomotive Works of the then London, Midland, and Scottish Railway he was appointed Assistant to the Welding Engineer in 1938. Three years later he became Assistant to the Works Metallurgist.

In 1944 Mr. Wise joined the Research Station of the Southern Railway at Ashford, as Senior Technical Assistant to the Chief Mechanical Engineer. In this position he

was responsible for welding development and control, non-destructive testing, and various engineering and metallurgical investigations. He was appointed Scientific Officer after the Station had become the

Sidney Wise

Research Department of British Railways at Ashford, in 1951, and was concerned with various investigations into rolling stock problems.

Mr. Wise took up his present position in the Engineering Division at Derby in 1953, and is in charge of the Properties of Materials Group, which is principally concerned with problems of fatigue in railway engineering.

BRANCH NEWS

Branch Secretaries

For the benefit of members who may wish to attend meetings at branches other than their own, or to make contact with other members we give the following list of Honorary Secretaries and their addresses:

Birmingham
J. R. Merther, A.M.I.Mech.E., 9 Brook Street, West Bromwich, Staffs. (Tel.: Broadwell 1500.)

Eastern Counties
W. Hearsum, 45 Bucklesham Road, Ipswich. (Tel.: Ipswich 78989.)

East Midlands
K. Houghton, B.Sc., M.I.Mech.E., 20 Shirley Road, Leicester.

East of Scotland
R. D. Berry, 13 Craig's Gardens, Edinburgh 2.

India
B. N. Majumdar, c/o Association of Engineers, 24 Netaji Subhas Road, Calcutta 1.

Leeds
M. W. Parkinson, 1106 Leeds Road, Woodkirk, Dewsbury.

Liverpool
H. R. Cox, M.I.N.A., 21 Oaklands Drive, Bebington, Cheshire. (Tel.: Rock Ferry 4242.)

Manchester
E. H. Lee, 349 Moorside Road, Flixton, Lancs.

North Eastern (Tees-side)
F. G. Batchelor, 5 Dionysia Road, North Ormesby, Middlesbrough.

North Eastern (Tyneside)
T. S. Nicol, Bolbec Hall, Newcastle on Tyne.

North London
J. F. Gibbs, 927 Great Cambridge Road, Enfield, Middlesex. (Tel.: Enfield 8701.)

Slough Section (N. London)
J. F. Gallagher, 3 Hazel Grove, Staines, Middlesex.

Preston
R. Robinson, Daneham, Pope Lane, New Longton, Preston. (Tel.: Preston 56221.)

Sheffield
G. W. Cragg, Highcroft, 22 Lilly Hall Road, Maltby, Rotherham, Yorks.

South London
J. P. Moore, A.I.M., 110 Kingston Road, Teddington, Middlesex. (Tel.: Kingston 1895.)

Medway Section (S. London)
P. Murrell, 21 Wayville Road, Dartford, Kent. (Tel.: Dartford 2920.)

South Wales
R. E. Phillips, 20 Bryn Road, Brynmill, Swansea.

South Western
G. R. Thomas, 2 Newcombe Drive, Stoke Bishop, Bristol 9.

Southern Counties
J. H. Gillespie, B.Eng., 12 Burlington Road, Southampton. (Tel.: Southampton 24833.)

West of Scotland
H. H. Mackintosh, 144 St. Vincent Street, Glasgow C.2.

Wolverhampton
J. W. Gethin, c/o John Thompson Ltd., Group Research Laboratories, Ettingshall, Wolverhampton.

APPOINTMENTS

Situations Vacant

Applications are invited for the appointment of a **Welding Engineer**. A degree in engineering or metallurgy, or equivalent qualifications is necessary, together with a sound knowledge of modern welding technology covering all classes and types of welding encountered in the structural engineering industry. Overall supervision of labour and negotiations with Trade Unions at shop floor level will be involved. Starting salary will be in accordance with the applicant's age and experience. Applications giving full details of experience, which will be treated in strict confidence, should be addressed to:

The Works Manager
The United Steel Structural Co. Ltd.
Frodingham Works
Scunthorpe, Lincs.

BRISTOL AEROJET LIMITED

Two Welding Development Engineers required to join a specialized team engaged on development and research into new techniques of welding.

Candidates should be of Higher National Certificate standard in Metallurgy or Engineering and have a sound basic knowledge of welding practice. Familiarity with inert-gas processes would be an added advantage.

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Please write giving details of age, qualifications and experience to:

MR. J. G. COLEE,
Room BJ/10
Bristol Aerojet Limited
Banwell, Weston-super-Mare
Somerset.

WELDING—A Chief Site Welding Engineer is required for a nuclear power construction project. He must have (i) sound practical experience of heavy, site welded, steel fabrications; (ii) ability to establish and maintain the highest possible welding quality; and (iii) an energetic disposition, able to get on well with people and to organize efficiently. An attractive salary will be paid to the right man.

All replies will be treated in strict confidence by a welding consultant who is advising on this appointment, and should be in writing to Box No. 230.

WELDING—A Chief Welding Engineer is required by a large Company in Scotland engaged in heavy welded plate fabrication of the highest quality. He will head a Welding Department which advises on all aspects of welding for the main works and for sites throughout Britain. This Department is already staffed but is being greatly expanded and is now provided with new, fully equipped metallurgical and welding laboratories, with associated offices, and machining and testing facilities.

Candidates should have an Engineering Degree or Corporate Membership of a Senior Engineering Institution. Sound practical experience of heavy plate work, particularly of the effect of welding procedures and methods on quality and dimensional accuracy, is important. Wide knowledge and experience of the arc and inert-gas welding processes and of the problems of welding a wide range of materials is required. Organizing and management ability will be taken fully into consideration.

Promotion opportunities exist beyond the position advertised. Assistance will be given with removal expenses.

All applications will be treated in strict confidence by a welding consultant who has been retained to advise on this appointment, and should be in writing to Box No. 231.

PROMINENT MANUFACTURER OF ELECTRIC ARC WELDING PLANT requires young ambitious **ENGINEER** for interesting work in his Sales Office, involving preparation of welding schemes, advice to Customers on all types of welding applications and quotations for the requisite plant. Well trained welding engineers looking for further scope are invited to apply for interview. Write Box BJ 1011, LPE Romano House, 399/401 Strand, London W.C.2.

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All other matters relating to advertisements for this section of the News should be addressed to the Executive Editor, 6 Ridge End, Hook Hill Lane Woking, Surrey (Tel. Woking 2981).

Copy should be sent by 6th of each month for publication in the following month.

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Subject IGNITRONS — RATINGS

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BK 24	1200	140	—
BK 24A	1200	140	Integral
BK 24B	1200	140	Clamp on
BK 34	2400	355	—
BK 34A	2400	355	Integral
BK 34B	2400	355	Clamp on
BK 42	600	56	—
BK 42A	600	56	Integral
BK 42B	600	56	Clamp on
BK 66	300	22·4	—

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BK 46	2·1	150
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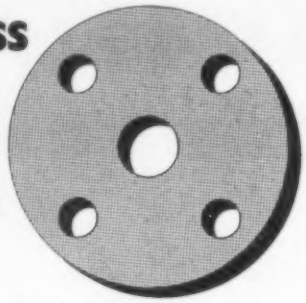

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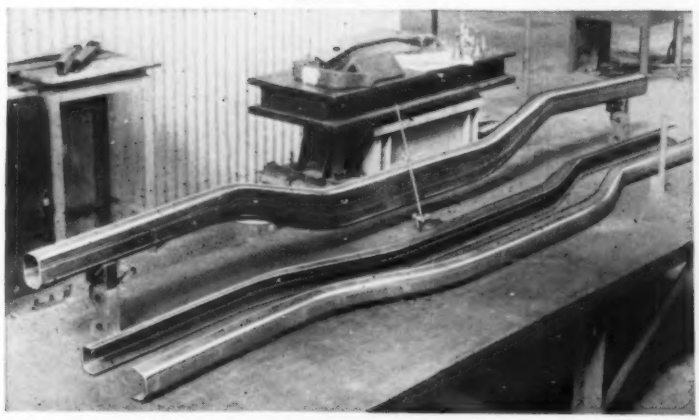

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